The AUTOMATIC ELECTRIC Technical Journal

a magazine devoted to progress in communication engineering

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Contributors to this issue

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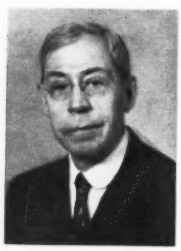

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H. E. CLAPHAM, *Editor*

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THE TYPE 45 ROTARY SWITCH

By R. L. HUFFMAN

SYNOPSIS: ***Need for a new rotary switch — indirect drive operation — new stopping teeth on end of armature—no adjustment needed for armature stroke — operating characteristics—manufacturing to permit high-speed operation—factory lubrication —six advantages of the new switch.***

FOR a number of years there has been a pressing demand in the telephone and electrical control fields for a high speed, heavy duty rotary switch having more positive action under severe operating conditions than switches heretofore available, requiring fewer and simpler adjustments for lower maintenance cost, and having a greater bank capacity. In the telephone field high speed ten-level switches have been urgently needed for finders, connectors, distributors, ringing interrupters, and timers. In the electrical control field there have been numerous requests for switches of this type for control of industrial processes, telegraph reperforator offices, and complicated testing circuits for aeronautical stress analysis. Automatic Electric Company's Type 45 Rotary Switch, a photograph of which is shown in Figure 1, was designed to fulfill these requirements.

The Type 45 Rotary Switch is of the indirect drive type: i.e., the wipers are advanced during release of the armature rather than during its operation. When the coil is magnetized it attracts the armature (causing the pawl to move into engagement with the next ratchet tooth), compresses the coil type driving spring so as to store mechanical energy, and operates the contact springs which are used as interrupter springs during automatic hunting. During operation of the armature the ratchet wheel and wiper assembly are held in position by a detent spring. Demagnetization of the coil allows the driving spring to exert force through the pawl on the ratchet tooth, and thus move the wiper assembly forward one step to the next set of bank contacts.

In the older type of rotary switch, when the pawl and ratchet reached the new position, the driving end of the pawl engaged an adjustable

block of metal (the pawl stop) which prevented the ratchet wiper assembly from overthrowing due to momentum, and thus positioned the wipers near the center of the bank contacts. However, the pawl stop did not receive the full force of the armature driving stroke since a rugged adjustable stop for the armature arrested the driving blow just before the pawl engaged the pawl stop.

Stopping Teeth

In the Type 45 Rotary Switch both the adjustable pawl and adjustable armature stops are replaced by a set of stopping teeth on the end of the armature. These engage the ratchet teeth and stop the overthrow of the wiper assembly and the force of the armature stroke. No adjustment of the stopping teeth is required. In addition, this arrangement does not have a tendency to bind, as did the pawl stop. Figure 2 shows the sequence of operations of the pawl and stopping teeth for one cycle of armature operation.

In the older type of switch it was necessary to provide an adjustment for the length of armature stroke. In the Type 45 switch this adjustment also has been eliminated. It is thus apparent that the adjustments needed are considerably fewer in number than on the previous type of switch. With elimination of the pawl stop, armature stop and stroke adjustments, the only remaining adjustments required are gauging and tensioning the interrupter and off-normal springs, setting the airline between armature and frame, tensioning the driving spring (a simple screw adjustment), and locating the bank so the wipers are centered on the contacts. For maintenance, the airline, interrupter springs and restoring spring may have to be readjusted occasionally.

The Type 45 Rotary Switch is designed to operate self-interrupted at speeds up to 70 to 75 pulses per second, or to operate from external pulsing at speeds up to 30 to 35 pulses per second on 46 volts d-c. The switch will function on voltages from 12 volts up. Off-normal springs for the operation of auxiliary circuits are also provided, with break, or break-make combinations.

Manufacturing Tolerances

To hold manufacturing and maintenance adjustment to a minimum it was necessary to keep manufacturing dimensions to very close tolerances. For example, all bearing holes, pins and shafts were reamed or centerless ground to a tolerance of $\pm 0.0005''$. Locating dimensions on the frame and armature were in some instances held to $\pm 0.001''$. Dimensions locating and defining the shape of the ratchet and armature stopping teeth were held to $\pm 0.001''$, and angular dimensions to 15 minutes. Special precautions were necessary to prevent the accumulation of excessive tolerances on the bank and wiper assemblies. The number of parts required to make these assemblies was held to a minimum, and suppliers were requested to furnish material with special tolerances.

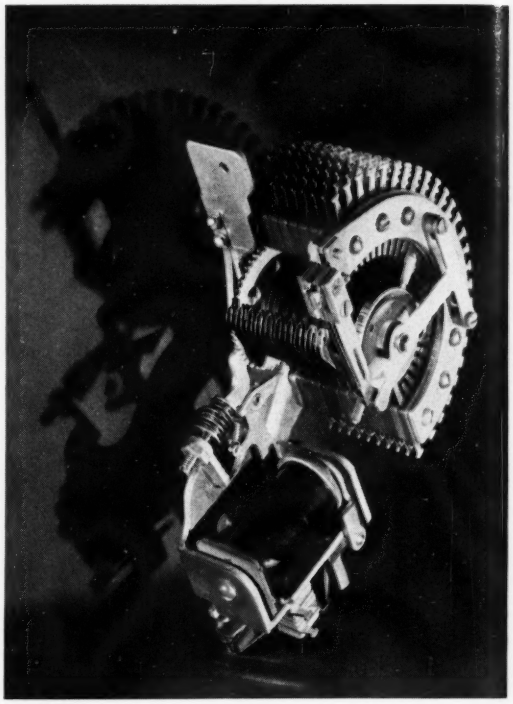

Figure 1. The Type 45 Rotary Switch.

To lengthen the life of the switch, its ratchet wheel and armature stopping teeth have been given a special heat treatment that puts a tough abrasion resisting case on them. The pawl is made of a special high impact abrasion resisting steel. It has been found by test that this combination of material and heat treatment gives maximum switch life and wear resistance.

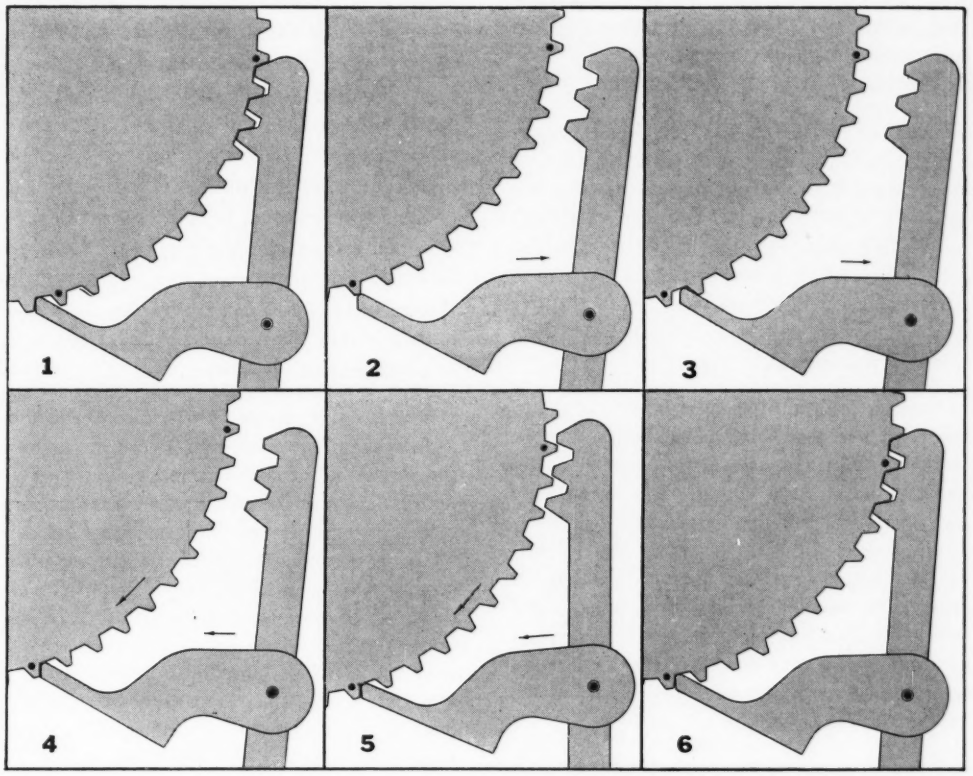

Figure 2. Cycle of Operation of the Type 45 Rotary Switch, showing action of pawl, armature stopping teeth, and ratchet teeth.

The pawl is suspended to the armature by a bronze alloy pin that turns in a hardened bearing in the armature. This combination has also been found to provide maximum wear resistance. The armature bearing consists of a hard drawn stainless steel pin operating in a cast bronze alloy bearing yoke. The bearing yoke is cast to such close tolerances that the only machining required is the reaming of the bearing hole.

Frame Design

The frame is of a one piece open type construction. The bank is mounted on one side so it can be built up to any desired number of levels without interfering with the frame. In the older type of rotary switch it was necessary, where more than six levels were required, to widen the frame by cutting it in two and welding on an extension which would accommodate a larger bank. Such a procedure is eliminated in the Type 45 Rotary Switch. The coil, armature, interrupter springs, wiper assembly, and bank assembly are attached to the frame. Except for the armature and coil core the frame comprises all of the magnetic circuit. The greater efficiency of this circuit contributes to the increased speed of operation of the new switch. Careful coordination of other design elements, including the length of the armature stroke, length of the armature arm, design of the driving spring, and mass of the moving parts, was also

necessary to obtain this high operating speed with a single coil self-protecting magnet. The bank mounting holes in the frame are of oblong construction, so that the wiper tips can be centered on the bank contacts merely by rotating the bank slightly around the wiper shaft centerline.

Providing for expansion of a telephone switchboard only partially equipped with switches is readily accomplished during manufacture by attaching extra banks to a shelf through a bracket, and multipling these to the existing switches. When expansion of the board itself becomes necessary, the bracket is replaced by a switch frame; the wiper assembly, coil and armature are then assembled to the frame.

The bank is built up as a unit. Contacts and brush springs are assembled between hard, noncompressible, moisture resistant, laminated plastic spacers that have been coated with a bakelite varnish. The bank is tightened during a pressure and baking cycle. During this cycle the varnish softens and adheres to the contacts, making a cemented bank assembly which is as strong and moisture resistant as a molded bank. This method of construction also provides a voltage breakdown between adjacent contacts and between contacts and ground of 2,000 volts, a-c, r.m.s.

Twin contact tips on the wipers, plus a high grade lubricating oil on the bank contacts, virtually eliminate "microphonics" in talking circuits. The wiper blades are assembled into pairs by projection welding them to metallic spacers. This assembly is held to a tolerance of $\pm 0.0005''$ to prevent the accumulation of excessive tolerances in the wiper assembly. The wiper pairs are then assembled to the ratchet wheel hub between varnished plastic spacers, and given a squeezing and heating treatment similar to that provided the bank. This results in a solid moisture resistant unit that also has a voltage breakdown of 2,000 volts, a-c, r.m.s.

The frame, bank assembly, and wiper assembly are so constructed that the switch can be built up into any number of levels (to a maximum of fifteen), without altering the basic construction of the switch.

In the past many switches have been designed with the brush springs located between adjacent wiper pairs so the wiper tips would not wipe over the brush springs and pick up an extra load. This design is not satisfactory where a switch must withstand a high voltage breakdown test, as it reduces the air gap between adjacent wiper pairs by one half. To increase the breakdown voltage many switches have been designed to mount the brush springs between wipers of the same pair, but the disadvantage of this scheme is that when one end of the wipers engages the last contact in the bank, the other end engages the base of the brush springs. Since on one position of the wipers the load is thus nearly twice as great as it is on other positions, it is necessary to run the switch at slower speeds to obtain smooth operation.

The Type 45 Rotary Switch has been designed to follow the latter scheme. However, to overcome the disadvantage of having the wipers pick up a double load each time the wiper tips pass over the brush springs, the banks were provided with 25 contacts, while each half of the ratchet wheel was equipped with 26 teeth. For 25 steps of the switch one end of the wiper blade rests on a contact, while the other is in space. On the twenty-sixth step one wiper tip moves off the twenty-fifth contact into space, and the other end steps onto the base of the brush springs. Thus the load picked up on the twenty-sixth step is the same as on all other steps.

The switch will accordingly operate more smoothly at higher speeds (particularly where the number of levels exceeds six) than it would if the load of one step were greater than the others. With this design, one step (the home position) in 26 will be ineffective. However, because of the short time interval (approximately 14 milliseconds) required for the wipers to traverse this space when operating self-interruptedly, this is no disadvantage. Where it is necessary from a circuit standpoint to have a wiper rest on a contact in the twenty-sixth (or home) position, an extra contact can be added during manufacture to those levels —usually private levels—requiring it.

Lubrication

The wiper hub is lubricated during manufacture with a high grade grease that retains its lubri-

cating properties at high and low temperatures for long periods of time, and should not require replacement during the life of the switch. The pawl, armature bearing, off-normal spring bushing and interrupter spring bushing are lubricated with an oil that in addition to excellent lubricating properties has a tacky or sticky characteristic which prevents it from spreading; consequently it stays where it is placed and does not move to unwanted areas as do most mineral oils.

The pawl tip and ratchet wheel teeth are lubricated with a mixture of oil and colloidal graphite. The oil in the mixture is the same as that used on the pawl and armature bearings, providing a medium that holds the graphite to the ratchet wheel teeth and prevents it from spreading to unwanted surfaces. The graphite affords lubrication to the teeth and pawl that will withstand the high pressures encountered at this point.

On tests of ten-level switches from factory production, operating self-interrupted at 70 steps per second, the switches exceed 10 million half-revolutions of the wipers. With slight readjustments and replacement of minor parts these switches were still serviceable. This is a 100% improvement over the old type of rotary switch.

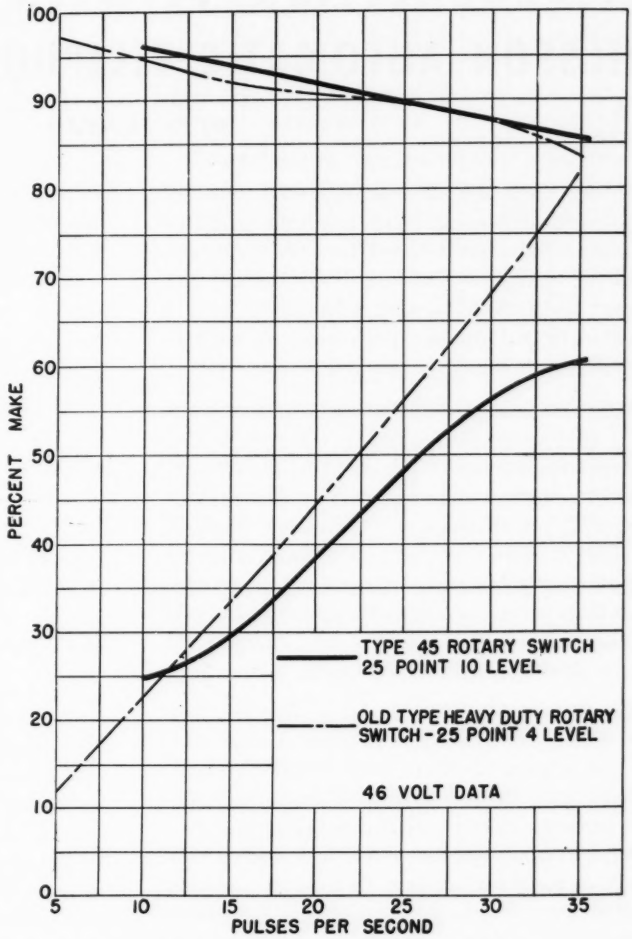

Figure 3. Speed-Pulse Ratio Curves for the Type 45 and old heavy duty Rotary Switches.

Figure 3 shows a comparison of the speed-pulse ratio curves of the Type 45 Rotary Switch and the old type of switch. The pulse range of the Type 45 is wider than that of the old switch, particularly at the higher pulsing speeds.

In making the Type 45 Rotary Switch available to industry, Automatic Electric Company believes that a new tool has been provided offering the following improvements over previous switches: (1) the serviceable life has been increased 100%; (2) the switch has fewer and simpler adjustments, with less frequent need for them; (3) it has more positive operation; (4) it can be expanded to greater capacity (increased number of levels) with ease; (5) it has a higher self-interrupted speed; and (6) it has a wider pulse range.

INTERCONNECTION BETWEEN STROWGER AND ERICSSON AUTOMATIC TELEPHONE SYSTEMS

By N. SALVESEN

***SYNOPSIS:** Comparison of Strowger and Ericsson automatic systems—use of translators and registers—paralleling connector scheme — features of two typical interconnections: a new Strowger office as satellite to an Ericsson main office, and a Strowger addition to an existing Ericsson office —Strowger equipment for replacement and expansion.*

IN the April issue of *The Automatic Electric Technical Journal* there appeared a discussion of the adaptability of Strowger Automatic telephone equipment, showing how practical and efficient interconnection with a Rotary (I.T.&T.) system is effected through relatively simple registering and translating equipment for routing calls.

With modification, the same principles of registering and translation apply to interconnecting Strowger and Ericsson automatic telephone equipment. The latter is manufactured by Telefonaktiebolaget L. M. Ericsson of Stockholm, Sweden. Specially designed registers and translators permit using Strowger Automatic equipment both to open new offices in an exchange area served by Ericsson offices, and to make additions for increasing the line facilities of existing Ericsson offices.

The Strowger system is a straightforward decimal system, in which the switches setting up a call normally operate successively in direct response to the impulses sent out by the calling subscriber's dial. Strowger switches are of a two-motion type. A vertical motion steps the wipers to a desired bank level. A horizontal motion then rotates them in on that level, and in the case of a group selector picks a trunk to the next rank of switches, or in the case of a connector chooses the terminals of the called station. The switches are individually driven, and do not depend on any common impulsing mechanism.

The Ericsson system, on the other hand, is of the motor-driven, register-translator type. The switches are two-motion, but operate with a horizontal motion which selects a bank multiple frame having twenty sets of terminals, and a radial motion which selects a particular set of terminals in the frame. The system operates on a non-decimal basis, since the called subscriber's directory number is dialed into a register, which in turn controls the movements of the switches. The impulsing is revertive, which means that the switches cause the registers to give up, one at a time, the impulses dialed into them by calling subscribers. In this way the registers direct the horizontal and radial movements of the switches to the desired terminals.

This fundamentally different principle of pulsing requires the use of special translators and registers for completing calls between Automatic Electric and Ericsson equipment. On calls from Ericsson to Strowger, translators are necessary to provide revertive pulses back to the registers in the Ericsson system and to translate these revertive pulses into decimal pulses corresponding with those sent out by the dial. The translated pulses then successively operate the Strowger switches to the terminals of the called station, in accordance with the dialed number. The entire number is not stored in the translator, but each digit is translated as it is received and immediately delivered directly to the Strowger switches.

Calls from Strowger to Ericsson are routed over Strowger switches in which the group selectors preceding the connectors are of the 20-level type. From the banks of these selectors trunks are run to the Ericsson connectors which establish the final connection to the called station. When a Strowger selector of this type is seized during a Strowger to Ericsson call, it is at once connected temporarily to a register, via the associated finder. The last three digits of the called number are stored in the

register and translated into revertive pulses for moving the Ericsson connector to the called station's terminals.

The registers and translators are needed only to establish a connection. When the last digit of the dialed number has been transmitted, they are immediately released and available for other calls. The register and translator finders may be either the two-motion Strowger type (as shown in Figures 1, 2 and 3) or the single-motion rotary type, depending upon which will better suit each particular project.

As an alternative to the register method of operation on Strowger to Ericsson calls, Strowger connectors can be installed with their banks multipled to the banks of the Ericsson connectors. In this case standard 10-level Strowger selectors would be used in place of the 20-level selectors. Registers and associated finders would not be required, since Strowger to Ericsson calls would not be routed over the Ericsson connectors but over the paralleling Strowger connectors.

The paralleling connector scheme considerably simplifies Strowger to Ericsson interconnection in that it eliminates storing and translating, and permits all calls originated by Strowger subscribers to be completed on a straightforward Strowger basis. The application of this plan depends to a large extent, however, upon economic factors and operating plans, particularly as they relate to future traffic developments and the retiring of old equipment.

Strowger to Strowger calls are in all cases completed entirely over Strowger switches, without the use of register and translating equipment, thus insuring to these calls the speedier operation inherent in systems wherein the switches are operated directly from the subscriber's dial.

The problems of interconnecting Strowger and Ericsson equipments involve conditions individual to the office or exchange area under consideration. These conditions generally concern subscribers' numbering plans, trunking arrangements, digit capacity of existing registers, and the type of Ericsson equipment used. However, since the underlying principles of interconnection are constant, we are limiting the scope of this article to two typical problems: (1) the installation of a Strowger office in an exchange area served by an Ericsson five-digit office, and (2) the installation of a Strowger addition to an existing Ericsson four-digit office.

New Strowger Central Office in Ericsson Exchange Area

Figure 1 shows diagrammatically a plan for installing a new 2000-line Strowger central office in an exchange area served by a 10,000-line Ericsson five-digit office. The subscribers' directory numbers in the Ericsson office are *10000* to *19999* and in the Strowger office are *52000 to 53999*.

The equipment in the Strowger office consists essentially of Strowger linefinders, outgoing Strowger-to-Ericsson pulse repeaters, first, second and third group selectors, and connectors. In the Ericsson office is installed Strowger equipment including outgoing Ericsson-to-Strowger pulse repeaters, trunk finders, translators, incoming second group selectors and registers with associated finders.

The first group selectors in the Strowger office are arranged so they absorb the digit *5* when it is dialed as the first part of a subscriber's directory number. The selectors may be of the ten or twenty trunks per level type, as suited to the particular project. The second and third group selectors in the Strowger office are standard 10-level, ten trunks per level types.

The Ericsson connectors are of the 500-line type. In each group of 1000 lines, one 500-line connector group serves lines *000 to 499* and the other serves lines *500 to 999*.

The incoming second group selectors in the Ericsson offices are of the two-digit, 20-level type. For the sake of clarity the twenty levels should be considered as two sets of ten levels each, lower and upper. Associated with each set of banks are a lower and an upper set of wipers, mounted on a switch shaft capable of making ten vertical steps. The wipers are so located on the shaft that when it is moved vertically (say) four steps, the lower wipers are opposite the fourth level of the lower set of banks, and the upper wipers opposite the fourth level of the upper set of banks. The trunks from the lower bank levels are run to Ericsson connectors serving *000* to *499* in each respective thousand group. In like manner, the trunks from the upper bank levels are run to Ericsson con-

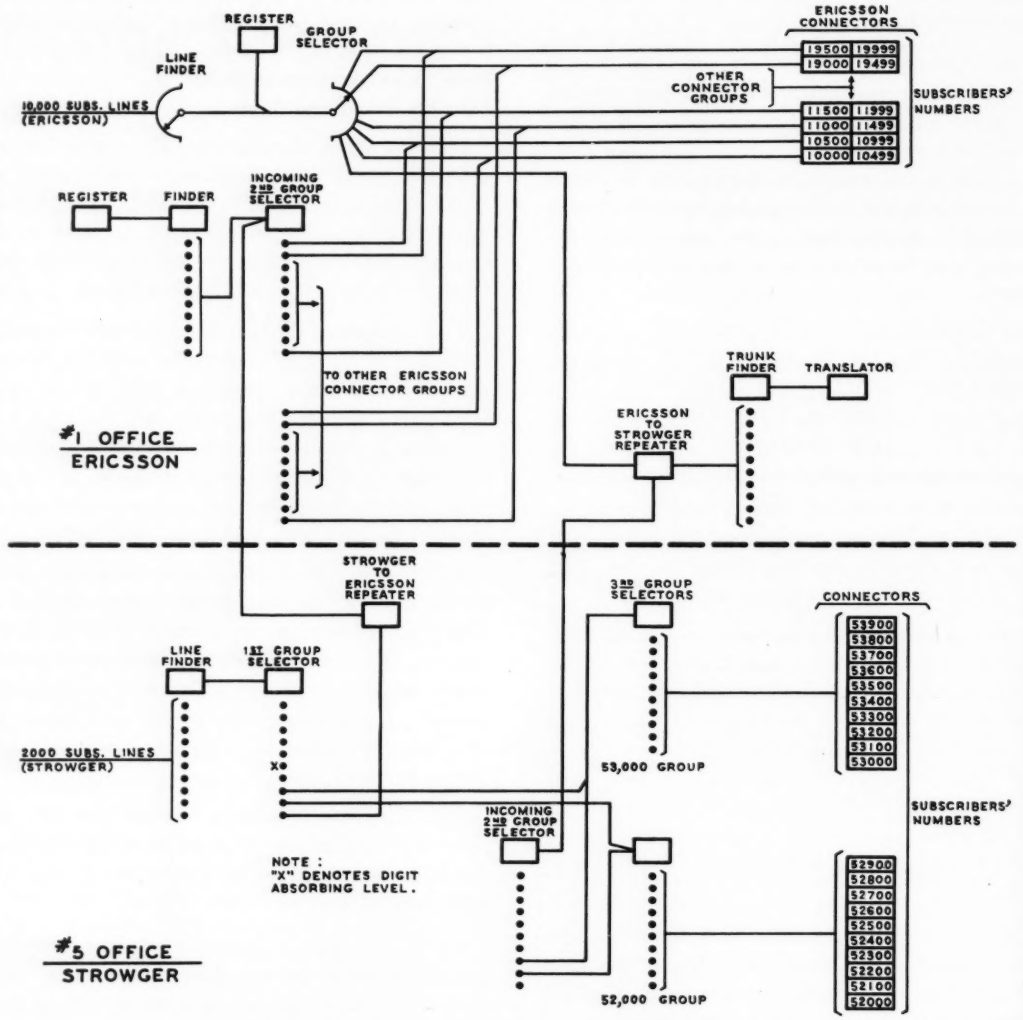

Figure 1. 2000-line Strowger Office Interconnected with 10,000-line Ericsson Office.

nectors serving lines *500 to 999* in the same thousand group. Thus the cables from levels *1* run to the *11000* group, from levels *2* to the *12000* group, and so on up to levels *0* which run to the *10000* group.

Let us imagine a Strowger-to-Ericsson call is about to be made. The station desired has the directory number *11624*.

The first digit dialed (*1*) causes the first group selector to step its wipers to the first level. The selector automatically rotates in on the selected level, and through the Strowger-to-Ericsson pulse repeater selects a trunk terminating on an incoming second group selector in the Ericsson office. The seizure of the incoming second group selector also causes an idle register to be connected temporarily to the selector, through the associated finder.

The second digit dialed (*1*) is not directed to the register but received by the incoming second group selector, causing it to step its wipers to the first level. The selector does not at this time rotate in on the selected level, nor is the calling line connected through to either the lower or the upper set of wipers, since it has not yet been determined to which of the two 500-line connector groups in the *11000* group the call will be routed.

The third, fourth and fifth digits dialed (*624*) are received and translated by the register. Each digit is sent out immediately upon translation, successively operating the incoming second group selector and the Ericsson connector. The third digit (*6*) indicates that the call must be routed to a connector serving lines *11500* to *11999*. The translator accordingly causes the incoming second group selector first to connect the calling line to the upper set of wipers, and then rotate them in on level *1* in order to select a trunk to an idle Ericsson connector in the *11500* to *11999* group. Further translation of the third digit (*6*), together with translation of the fourth and fifth digits (*24*), operates the Ericsson connector to terminals *24* of the *11600* group, thus completing the connection to station *11624*.

If the called station is idle it is automatically rung. If it is busy, or if all-paths-busy is encountered, the calling party receives the customary busy tone.

The register is released and made available for other calls as soon as the last digit has been transmitted.

Let us imagine an Ericsson-to-Strowger call is about to be made. The station desired has the directory number *52346*.

The five digits dialed by the calling party are received and stored in the Ericsson office register in the usual manner. Under control of the register, and as determined by the first digit (*5*) of the called number, the group selector in the Ericsson office operates to select a trunk to an idle second group selector in the Strowger office, via the Ericsson-to-Strowger trunk repeater. The seizure of the repeater causes an idle translator to be connected temporarily to it, through the trunk finder. The translator sends revertive pulses back to the register in the Ericsson system. These pulses clear out the register and transfer into the translator the digits previously stored in the register. These digits, corresponding to the second, third, fourth and fifth digits (*2346*) of the dialed number, are translated into proper decimal pulses and sent out by the translator to operate the Strowger switches. In the usual Strowger manner, these decimal pulses first step the second group selector to the second level and select a trunk to an idle third group selector in the *52000* group. Next they step the third group selector to the third level and select a trunk to an idle connector in the *52300* group. Lastly, they move the connector to terminal *46*, thus completing the connection to station *52346*.

Finally, let us imagine a Strowger-to-Strowger call is being made, to station *52346*.

The first digit dialed (*5*) causes the first group selector to step its wipers to the fifth level, but the selector immediately releases and returns to its normal position. The second digit (*2*) again operates the first group selector, causing it to step its wipers to the second level, rotate in on that level, and select a trunk to an idle third group selector in the *52000* group. The dialing of the remaining three digits (*346*) successively steps the third group selector to the third level—where it selects a trunk to an idle connector in the *52300* group—and then operates the connector to terminal *46*, thus completing the connection to station *52346*.

Strowger Addition to Ericsson Office in Single Exchange Area

Figure 2 shows diagrammatically a plan for installing an addition of 1000 lines of Strowger equipment to an existing 3000-line four-digit Ericsson office in a single office exchange area. The subscribers' directory numbers are *1000* to *3999* for the Ericsson subscribers and *4000* to *4999* for the Strowger subscribers.

The Strowger equipment consists essentially of Strowger linefinders, first and second group selectors and connectors, plus register and translating equipment for routing calls between the two systems.

The first group selectors in the Strowger equipment are of the combined one- and two-digit, 20-

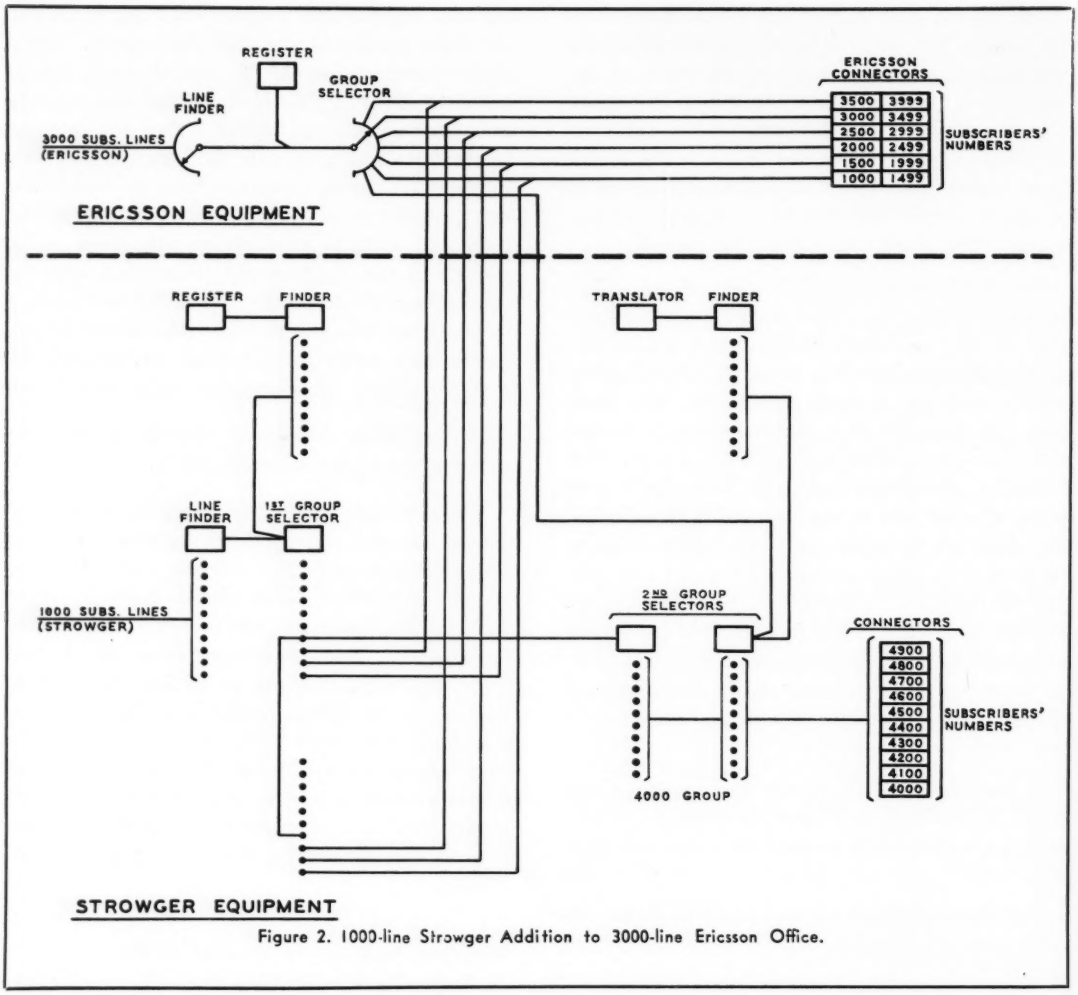

Figure 2. 1000-line Strowger Addition to 3000-line Ericsson Office.

level type. These selectors function like the 20-level incoming second group selectors in the Ericsson office described in connection with Figure 1, except that on levels trunking to Strowger selectors (for example, level 4 in Figure 2) it is a one-digit switch, operating like a standard Strowger group selector. When this selector is seized it is connected at once to a register via the associated finder. The register is used only in establishing Strowger-to-Ericsson calls, and on Strowger-to-Strowger calls is released immediately after the first digit of the desired directory number has been dialed.

The second group selectors in the Strowger equipment are of the standard 10-level, ten trunks per level type.

On Strowger-to-Ericsson calls a Strowger first group selector, an associated register and an Ericsson connector are used for completing the call. The operation of these switches is the same as described for Strowger-to-Ericsson calls in connection with Figure 1. The group selector in Figure 2 operates like the incoming second group selector in the Ericsson office in the first figure. In response to the initial digit the first group selector steps its wipers to the dialed level. Then, under control of the register, it connects the calling line to either the lower or the upper set of wipers and

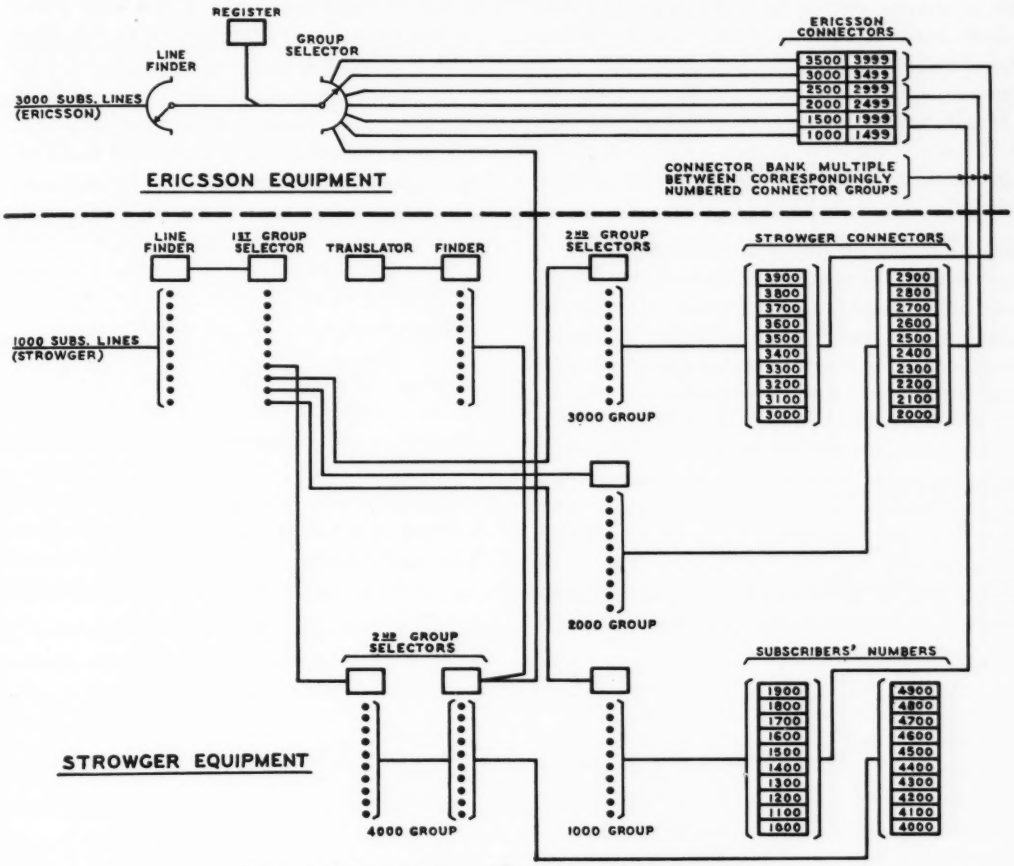

Figure 3. Strowger-Ericsson Office with Multipled Connectors.

rotates in on the dialed level to select a trunk to an idle Ericsson connector. The Ericsson connector then, also under control of the register, operates to the terminal of the desired station.

Ericsson-to-Strowger calls are completed in the same manner as described for similar calls in connection with Figure 1, except that in this instance third group selectors are not used since the subscribers' numbering plan is on a four-digit basis.

Strowger-to-Strowger calls are completed on a regular straightforward Strowger basis. The first group selector functions as a standard one-digit Strowger group selector. In response to the first digit dialed (*4*) the selector steps its wipers to the fourth level, rotates in on the level and selects a trunk to an idle second group selector. The second digit operates the second group selector to the level corresponding to the dialed digit and selects a trunk to an idle connector. The final two digits dialed operate the connector to the terminal of the called station.

Use of Strowger Equipment in Replacement and Expansion Plans

In cases where all or part of the equipment in an existing Ericsson office is reaching the end of its useful life, and consideration is being given to its eventual replacement by modern Strowger equipment, such a replacement may readily be

accomplished on a gradual conversion basis. Additions of suitable sizes of Strowger equipment may be made from time to time, thus gradually retiring old and worn out Ericsson equipment. The most economical plan under such conditions would be to install Strowger connector groups paralleling the Ericsson connector groups. Figure 3 shows diagrammatically such an installation as applied to the plan shown in Figure 2.

The advantage of this plan is that the Strowger switches would be of standard type, since no registering and translation would be required on Strowger to Ericsson calls. The paralleling connector groups would fit in with the final conversion program, permitting its completion without interference with service and without changes in subscribers' directory numbers. Thus the initial Strowger installation would form the nucleus of an eventual complete Strowger office. The economy of such a plan is at once apparent, since special 20-level switches would not be required for first group selectors, and the register and register-finder equipment used on Strowger-to-Ericsson calls would not be needed. This reduces to a minimum the amount of special equipment which would have to be discarded when the final conversion to full Strowger operation is completed.

In the plan shown in Figure 3, the banks of the Strowger type connectors are multipled to the banks of correspondingly numbered hundreds in the Ericsson connector groups. The registers and associated finders have been eliminated, and the 20-level first group selectors have been replaced by standard Strowger 10-level selectors. Second group selectors for the *1000, 2000* and *3000* groups, and connectors for the paralleling Strowger connector groups, would be provided in quantities sufficient for handling Strowger to Ericsson traffic. By this method all calls originated by Strowger subscribers are completed entirely over standard Strowger switches.

Equipment for toll and special services and the methods of handling these services have purposely been omitted since their provision does not present any problem which would alter the plan of interconnection.

THE DIRECTOR IN AUTOMATIC TELEPHONE SWITCHING SYSTEMS*

By ARTHUR BESSEY SMITH

***SYNOPSIS:** Universal numbering and tandem trunking facilitated by the Director—development of a Director system for the London automatic telephone exchange—Director terminology—principle of call registry—devices associated with the Director—translation and impulse sending—discussion of circuits — recent improvements in the Director.*

THE telegraph was invented in 1837 by Morse. In 1876 came Bell's invention of the telephone. By this time the switching of telegraph lines had developed into a definite system, characterized by plugs and jacks for easy connection and disconnection. Each connection lasted for a relatively long time—hours often running into days.

The first telephone switchboards were very much like those telegraph boards. But the telephone naturally required many connections and disconnections per hour, each connection lasting only a few minutes. This led to making the plugs and jacks smaller and easier to handle.

It is a remarkable fact that very soon after Bell's invention the first attempts were made to perform telephone switching automatically ("to do by a machine that which formerly was done by hand"). And about 1891 the work of Almon B. Strowger started, which developed into that of Automatic Electric Company. It was the adoption of this system of automatic switching for the London, England, telephone exchange which led to the invention and development of the "Director", the subject of this article.

The Director is a telephone switching device which stores the dialed call number and then sends out decimal impulses which guide the connection to the desired telephone office and to the called line.

When electric light and power came to London, authorities ruled that all wires must be laid underground. The first telephone system in London, entirely manual like others of that era, was also forced to put its wires underground. In addition to slowing the growth of telephone use, this tended to fix the routes of telephone cables and make it difficult to open new routes between offices as new offices were opened. To use tandem trunking was cheaper than to install direct trunks between all offices.

The plan of direct trunks with straightforward dialing has much to recommend it. There being no Director, there is no storage of impulses and no consequent loss of time. The subscriber pulls the call number, and when the dial gets home from the last digit the connector has arrived at the called line. There remains only the short time interval necessary to test the line and, if it is free, to start the ringing—which the subscriber can hear. Also, there is the psychological aspect: the subscriber has been usefully employed and his wait is short.

It is tandem trunking which makes the Director necessary, as also the great desirability of reaching a certain telephone by the same call number no matter where the calling subscriber may be located —the universal numbering plan.

Tandem trunking and the Director received serious consideration at an early date in the Western Hemisphere also. In fact, the Director was installed in Havana, Cuba, and in a P-A-X in Kansas City, Missouri, before the London system was put into service.

A paper presented at the Winter general meeting of the American Institute of Electrical Engineers, at Pittsburgh, Pa., January, 1948. Reprinted by permission.

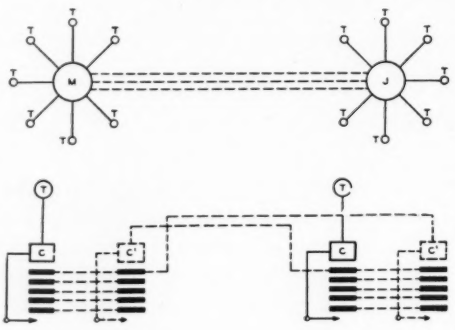

Figure 1. Two Exchanges, not Universal Numbering.

The Director sometimes affords good service to groups of small communities. If it is desired to permit subscribers to dial anywhere in a county without intervening operators, some paths may use direct trunks but many others will pass through switching points.

The present day prospect of nation-wide toll dialing in the United States—for which the Director is ideally suited—makes an understanding of the Director both timely and advisable.

Universal Numbering

Consider two small towns, not too far apart, each served by a 100-line automatic switchboard with only 80 lines in use. Figure 1 (disregarding the dotted lines) shows such an example. All calls in each town are made with two digits, and only connectors are needed. The rectangle *C* represents the mechanism and the five heavy lines underneath represent the ten levels (ten sets of contacts per level).

If someone decides to permit the subscribers to dial freely anyone served by the two switchboards, the dotted lines and switches may be added. There may be incoming connectors *C'* whose banks are multipled onto the banks of the local connectors *C*. Suppose that the top level of each local connector is set aside for trunking to the other board. Thus, any subscriber in the *M* office will dial two digits to reach others in the same town, but must prefix *O* to reach any telephone in *J*. Likewise, any *J* subscriber must prefix *O* to reach any telephone in *M*.

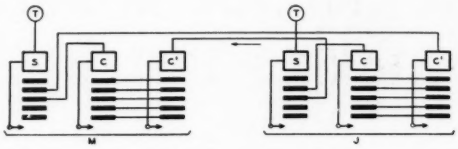

Figure 2. Two Exchanges, Universal Numbering.

The following situation arises. To call telephone *25* in the *M* region from any other telephone on the *M* switchboard requires dialing only *2* and *5*. But to dial the same telephone from any instrument connected to the *J* switchboard requires the user to dial *025*. This is *not* universal numbering.

Now consider Figure 2, where each of the two switchboards now has selectors *S* as well as connectors *C*. Every telephone has a 3-digit call number. As sketched, the telephones in *M* are in the *300* group and those in *J* in the *400* group. The former telephone *25* in *M* can now be called by dialing *325* in either town. It is thus with all lines. This is *universal numbering*.

Tandem Trunking

Let the four offices *E, J, K, M* (Figure 3) of a multi-office exchange be interconnected as usual by direct trunks. To serve a new region, office *X* is built. By reason of the local geography it would

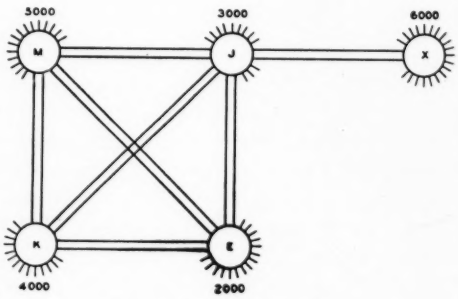

Figure 3. Tandem Trunking.

be too expensive to install direct trunk groups between the new office *X* and each of the older offices. Hence it is decided to have all calls from and to the *X* office switched at *J*. Any call from *E* or *K* or *M* would be dialed to *J*, where an additional digit would reveal that the call goes to *X* instead of to telephones connected to *J*. This is tandem trunking. If there is no Director, or its equivalent, universal numbering is not possible in such circumstances.

Notice also that if a subscriber in *J* calls one in *X*, he will dial, for example, four digits. But if a subscriber in *E, K* or *M* desires to call a telephone in *X*, he must first dial a digit to get *J*, then follow with the call number for the *X* telephone. Thus the number actually dialed will depend on where the caller is located, and it is not universal numbering.

But now let us place in each of the five offices a number of switching devices known as Directors. Each of these has been so designed that it can direct or guide a call to the desired distant office no matter what route it must take. Each of these Directors is accessible to all calls coming from subscribers in its own office. It is convenient to arrange equipment so that when a subscriber initiates a call he will as usual get a first selector, and an idle Director will at once be associated with that first selector.

The entire call number (for example, *6258*) will be dialed into the Director and registered there. The Director has been endowed with enough electrical and mechanical judgment to know from the first digit *6* that it must send the digit *3* into the first selector to extend the line to the *J* office, following this by sending the digit *6* into an incoming selector in the *J* office to cause it to rise to the group of trunks leading to the *X* office. After this, the Director will send the rest of the call number, *258*, which operates switches in the *X* office to connect to the desired line.

The other offices are likewise equipped with Directors having equal abilities, so that no matter where you are in the city, you can dial your friend in office *X* by the one call number, and you will get the right telephone. This is how the Director permits *universal numbering*.

This article describes the structure of the Director, how it works, and the variety of things which it can do. It does not attempt to deal exhaustively with the basic principles of tandem inter-office trunking, nor with the most economical use of the equipment. But it does show the flexibility of the Director—how it can be made to serve the exchange designer, and through him the public.

The London Automatic Telephone Exchange

At the beginning of January 1922, Automatic Electric Company was asked to develop an apparatus which would enable the London exchange to convert to automatic switching without the installation of direct trunks between all offices. Regular Strowger type numerical switches would extend the connections to their destinations.

M. L. Nelson and R. G. Richardson worked out the general plan and the circuit details, and by January 6 completed the first drawing showing practically all the details of a working Director. Though there have been numerous changes since, many of the features of that first layout were fundamental and have remained.

In 1924 a Director system was built and installed in the Havana, Cuba, exchange.

In the spring of 1923 John E. Ostline went to England in charge of further development of the London circuits. Out of his work came many improvements, some of great economic value. In 1924 construction of the apparatus for London was begun, and in 1927 the first of it was cut into service. Since then progress of research and development on the Director has been fairly steady.

First Aspects of the London Director

The situation may be illustrated by the following considerations which presented themselves to the designer:

(1) Universal call numbers, such as DAVis 8019.

(2) Tandem trunking

(3) Straight Strowger dialing of impulses, clear through to the distant office.

(4) Trunks to manual offices with call indicators for the operators, at least during the transition period.

The use of office names (such as Davis, Monroe,

or Humboldt) is a device to aid the memory of the subscriber. The arrangement of the letters of the alphabet on the dial is well known. The first letters of the office name—those dialed—are known as the "office code": e.g., *"DAV"* for *"DAVis"*. Dialing the office code *(DAV)* results in a "decimal equivalent" *(328)*.

The coming of the Director has required the use of the above and certain other words and expressions, each with a definite meaning, to avoid confusion. I will illustrate with the call number "DAVis 8019":

(1) *DAV* is the office code.

(2) *328* is the decimal equivalent of the office code.

(3) *MNOP* or other digits form the *directive*. By the action of the Director they are derived from the office code, and guide the call to the distant office. The number of digits in a directive depends on the route.

(4) *Directive selectors* are those which are in the train leading to the distant office. Each is operated by one digit of the directive.

(5) *8019* is the *terminal number*. As usual, the digts are called "thousands", "hundreds", "tens" and "units".

(6) The *thousands selector* and the *hundreds selector* are in the distant office, and handle the digits indicated by their names.

(7) The *connector* connects to the called terminal.

The London situation led to the following first approach:

(1) Carry the terminal number through unchanged (such as *8019*).

(2) Transform the decimal equivalent (such as *328*) into a directive (one to six digits) to steer the call to the distant office.

(3) Let the Director store all digits dialed by the subscriber, transform the decimal equivalent of the office code into a directive, send it, and repeat the terminal number unchanged.

The Director was composed of the following subordinate devices:

(1) The inward path, which guides the dialed impulses into the Director.

(2) The *ABC* register, on which the three decimal equivalent digits are stored.

(3) The terminal number register, on which the four digits of the terminal number are stored. (No provision was made for party lines.)

(4) A register sequence switch to guide the incoming digits, each to its appropriate register.

(5) A translator, to change the *ABC* code (its decimal equivalent) into the directive, having from one to six digits.

(6) An outward path from the Director to the first directive selector (in the originating office), from where the path will be extended to the distant office and the called line.

(7) An impulse generator, a device which generates correct impulses to be sent over the outward path.

Having seen the general plan of the Director, we become interested in the various circuits used to accomplish the results enumerated. It is not practical to discuss the entire circuit assembly at present, for it is too complicated. However, there are certain key circuit devices which merit immediate attention.

Call Registry

The registry of the call number is outlined in Figure 4. The telephone line comes through such non-numerical switches (marked *"Non"*) as may be used. These may be lineswitches or linefinder switches. The trunk passes to a group of trunk relays, where two chief paths run to the banks of a group of linefinders, presided over by a call distributor. The latter sends one of the linefinders to seek the incoming call. Thus it is connected to an idle Director. Single line sketches and symbols indicate the registry parts.

The incoming path from the subscriber passes through a slow relay (marked *"Slow Series"*) to the wiper of the register sequence switch. From the bank of this switch wires lead to the *ABC* code register and to the four digit registers for the terminal number *("Th", "H", "T" and "U")*.

The first digit (for example, $D=3$) operates the motor magnet *MM* of the code *A* register to

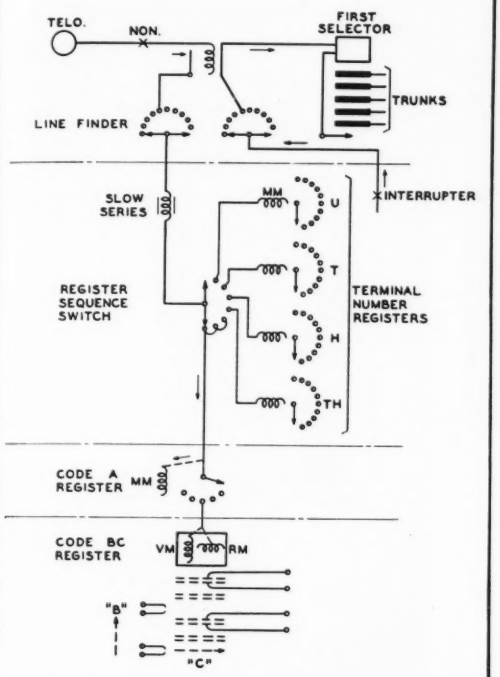

Figure 4. London Plan, General, Call Registry.

contact *3* on the bank. At the same time, the slow relay has energized the motor magnet of the sequence switch, so that at the end of the impulses the slow relay falls back and de-energizes the motor magnet, whereupon the wiper moves to the next bank contact. The next two digits from the telephone operate first the vertical magnet *VM* and then the rotary magnet *RM* of the code *BC* register. This is a two-motion Strowger switch, only four levels and four contacts per level being shown. The second digit (for example, $A=2$) lifts the wipers to the second level, and the third digit (for example, $V=8$) rotates them in to the eighth set of contacts on that level. In the meantime, the slow series relay of the sequence switch has advanced the wiper to contact *4*.

It is now clear how the remaining digits for the terminal number are directed successively to the motor magnets for the thousands, hundreds, tens and units registers.

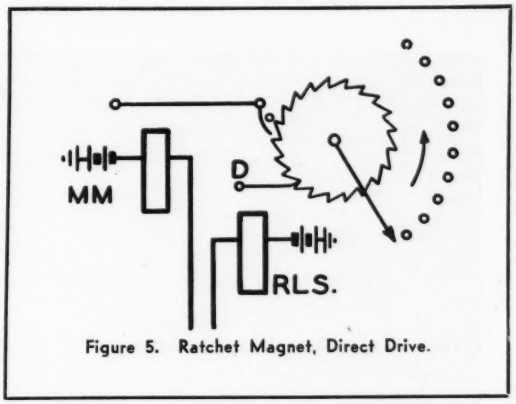

Figure 5. Ratchet Magnet, Direct Drive.

Thus by the positions of the wipers of the *BC* register we have a recording of the office code (its decimal equivalent), and by the positions of the four wipers of the terminal register an indication of the terminal number as it appears in the telephone directory.

Magnet Ratchets

Two ratchet devices are used, each with its own properties and performances. They enable circuit designers to obtain valuable results.

Figure 5 illustrates the direct magnet drive, used in the minor switch of Figure 6, and the vertical and rotary movements of the Strowger switch of Figure 7. When the magnet *MM* in Figure 5 is energized, the wipers move to the next contact. When the magnet releases, there is no circuit change—the ratchet is ready for the next step. Such a ratchet action moves against a restoring force—gravity in the vertical movement of the Strowger switch; a spring in its rotary motion and in the minor switch. In each case there is a detent *D* which prevents the ratchet teeth from moving backward. Return to normal is accomplished by a release magnet rise which pulls out the detent. The minor switch is used for the register of the digits of the terminal number, while the Strowger switch is used for the *BC* code register.

Figure 8 illustrates the spring drive used in the rotary lineswitch (shown in Figure 9). When the magnet *MM* in Figure 8 is energized by grounding *A*, the pawl engages the next tooth, but the wipers do not move. When the magnet releases, the spring drives the wipers to the next contact.

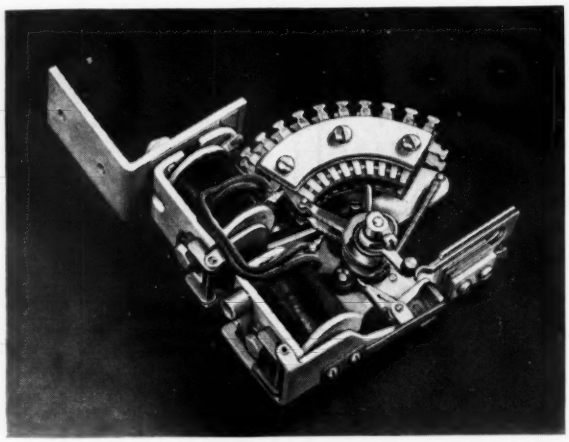

Figure 6. Minor Switch

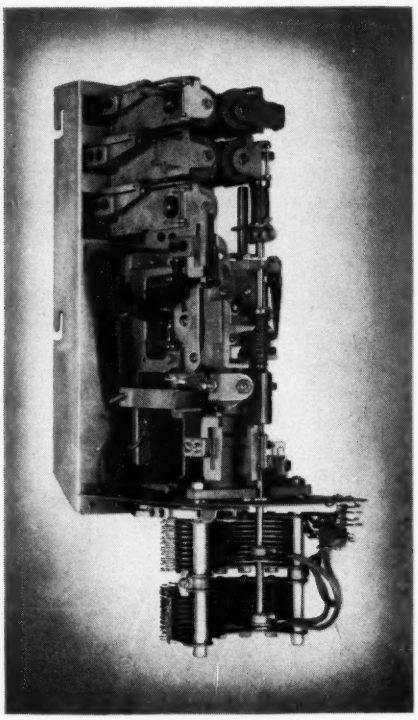

Figure 7. Strowger Switch.

This type of switch is returned to normal by causing the motor magnet to buzz like a doorbell (grounding *B*), so driving the wipers around the circle to the home position. This system is employed in the register sequence switch and elsewhere.

The Impulse Sender

Figure 10 illustrates the basic principle by means of which properly registered digits can be sent over the outgoing path or loop to the selectors. Suppose that each of the three registers, *H*, *T* and *U*, can be set by hand to any desired digits. I will assume *3-2-5*. Let the sequence switch *Seq.* be arranged to be moved by hand from its home contact to each of its bank contacts in sequence.

The impulse sender itself, as here abstracted, consists of a rotary switch with wipers *W* and *W'* stepped by a motor magnet *MM*. This is of the spring-drive type described above. A stop relay is connected to the wiper *W*.

In the upper right corner of the figure is the loop leading to the first selector, and through it to other selectors in the train. Two relays close it normally, by their back contacts: relay *D*, wired to wiper *W'*, and the interrupter relay *IR*, controlled by the interrupter itself. The interrupter *I* is steadily running at the rate of ten impulses per second, and the ratio of break to entire period is correct to operate the numerical switches in the train.

Two functions are essential: starting interruptions of the loop with a full-time break (not part of one), and stopping the sending when there has been sent the number of breaks indicated by the setting of any one of the registers.

We have set by hand wiper *H* at *3*, wiper *T* at *2*, and wiper *U* at *5*. We next set the sequence switch onto the *H* contact of its bank. Then we press the start key and hold it down.

If the time of pressing happens to be too late in an impulse of the interrupter, relay *IR* will fail to pull up, or make only a feeble or partial response, which does no harm. But the next time *I* closes, it will operate *IR* for the full period. This energizes the motor magnet *MM*, which pulls its armature to cause its pawl to engage a tooth. When

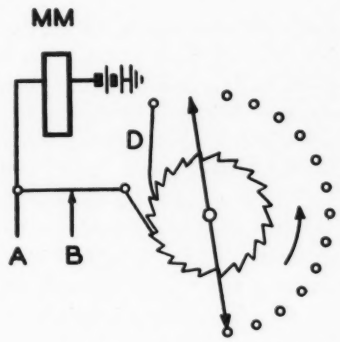

Figure 8. Ratchet Magnet, Spring Drive.

IR falls back, *MM* de-energizes and drives the wipers *W* and *W'* to the next contacts. Here *W'* operates relay *D*, which pulls up and remains operated to the end of this digit, opening its contact and thereby putting the loop entirely into the control of the *IR* relay.

The next impulse from *I* operates *IR* as before, causing *MM* to advance the wipers to contact *1*.

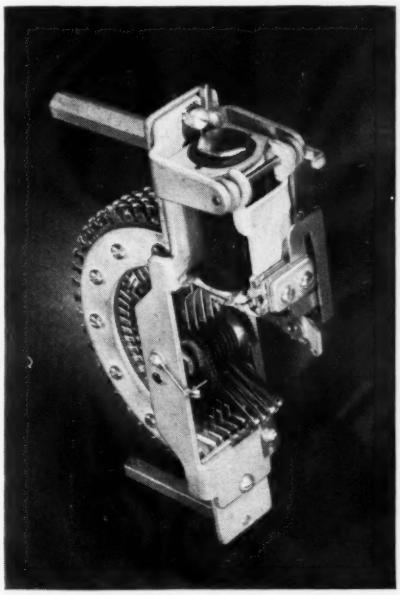

Figure 9. Rotary Switch.

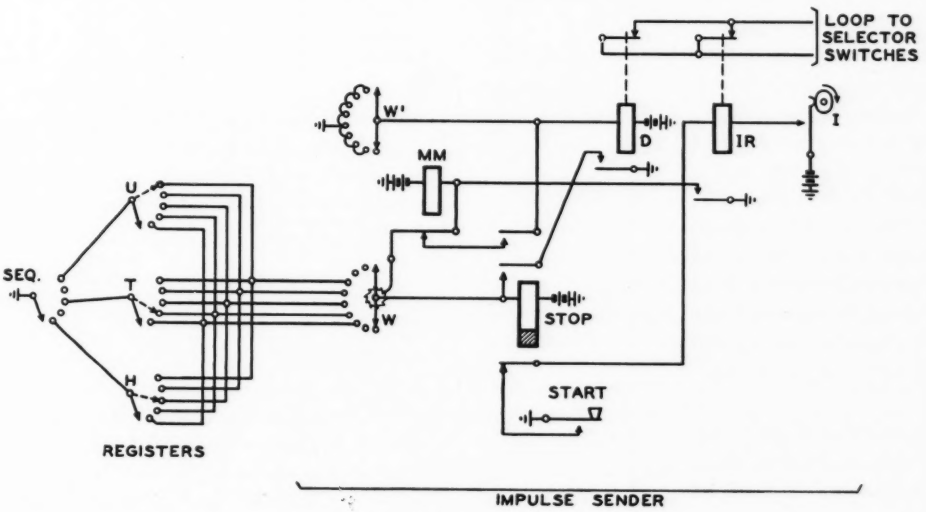

Figure 10. Register-to-Sender Relationship

The arrival of wiper *W* at contact *1* permits the stop relay to find out if it is grounded. Since it is not, two more impulses bring the wipers to contact *3*, which is grounded by our setting of the *H* register and the position of the sequence switch. At once the stop relay pulls up, breaks the start wire, and ends the sending of three impulses over the loop. There were only three impulses, and all of them were perfect.

In addition to stopping the impulses, the stop relay locks itself to ground on a contact of relay *D*, and also connects the self-interrupter contact of the motor magnet to wiper *W'*. At once the motor magnet starts to vibrate, and thus drives the wipers *W* and *W'* around the circle to the home position. Here the ground is removed from *MM* and relay *D*, the latter releases the stop relay, and ("start" being opened) the sender is ready for the next digit. Now we may move the sequence switch to the *T* contact, close the start key, and the sender will do the same process all over again, this time sending two good impulses. Moving the sequence switch to *U* will cause the same to be done for the units digit.

Translation: Decimal Equivalent into Directive

Consider the *ABC* code registers which were discussed in connection with Figure 4. The *A* register is a simple rotary switch of the "minor switch" type, and is set by the decimal equivalent of the first letter. This connected the impulse circuit to the vertical magnet, then to the rotary magnet of the selected *BC* register. This Strowger switch registered the *B* and *C* digits by its "up and around" movement of four wipers.

Now consider Figure 11, which illustrates the translation of the decimal equivalent of the office code.

Each Director has one code *A* register, to whose bank are wired eight code *BC* registers. I have illustrated this with only three of them. From the *A* register bank contacts the wires run to the magnets of the *BC* switches. The wipers of all the *BC* switches are multipled like to like, and run to the bank of the sender sequence switch. The banks of the *BC* switches are wired separately to one side of an intermediate distributing frame (IDF). The other side of that IDF is wired to the bank of the sender switch, where the sending of impulses over the loop will be governed. In this simplified illustration I have shown only two wipers for each *BC* switch. There were six wipers on each switch as planned for London.

Let us assume the following relations:

Decimal Equivalent	*Directive*
243	32
324	41
433	53

On the IDF, jumpers would be run as shown. For example, the No. 2 BC switch bank contact *43*

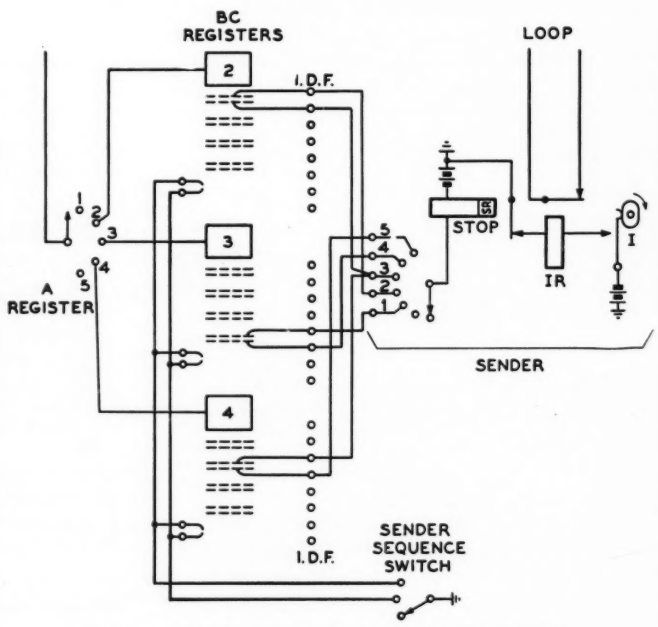

Figure 11. Translation of Decimal Equivalent into Directive.

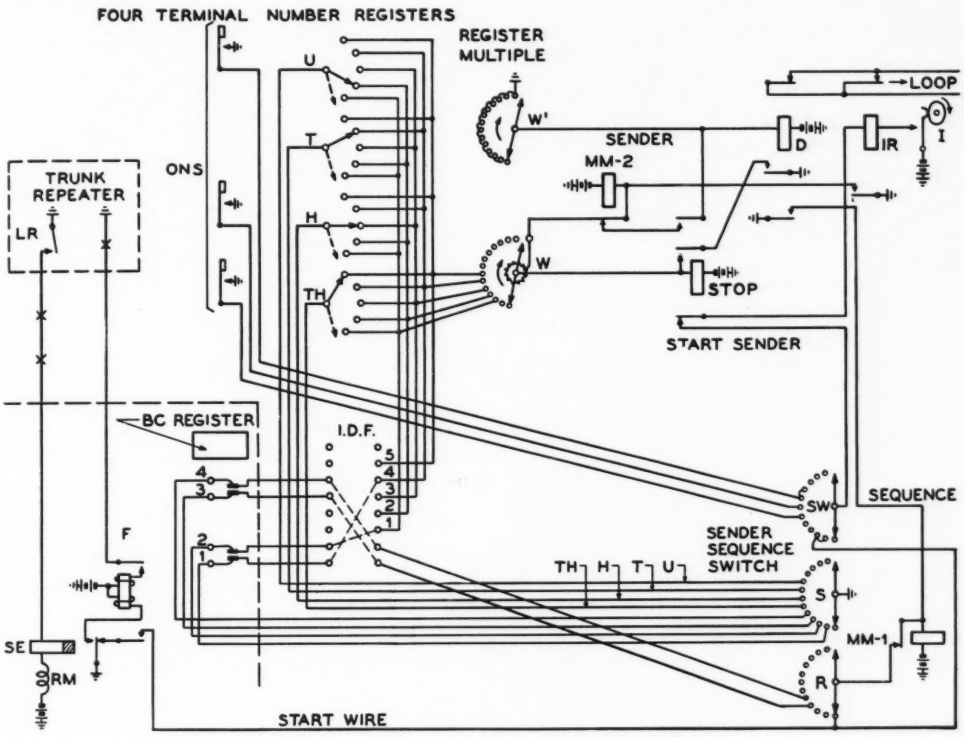

Figure 12. Registers and Sender Details, Assembled.

would have its bottom contact of the pair wired to *3* on the right side, and its upper mate wired to *2* on the right side. The other jumperings are self evident. In practice, all the bank contacts of the eight *BC* switches are similarly jumpered, according to the pathways which each inter-office call must take.

If the call which we are considering be *243*, the *A* switch will be on its No. 2 bank contact, and the No. 2 *BC* switch will have its wipers resting on its fourth level, and the third pair of contacts. Now, when ready to translate and send, the sender sequence switch will move one step, thus grounding all the lower wipers of the *BC* switches. Only the lower wiper of the No. 2 switch is connected—the others are normal and open. This move of the sequence switch starts the sender, which performs as described in connection with Figure 10, cutting off when three impulses have been sent. Then the sequence switch (Figure 11) will move to its next contact, switching the ground to the upper wiper, and start the sender on its next round.

The performance is similar for any other decimal equivalent.

In the actual case of four wipers for each *BC* switch, the sender can transmit four digits in the directive. The maximum number of digits in the directive determines the number of wipers needed.

It is its ability to move to a desired position any reasonable number of wipers that allows the Director to send out almost any kind of directive, one digit for each wiper which has been set. If the office code has only one digit, and the directive might have as many as four digits, a minor switch (rotary motion only) with four wipers can perform the operation. If the office code has two

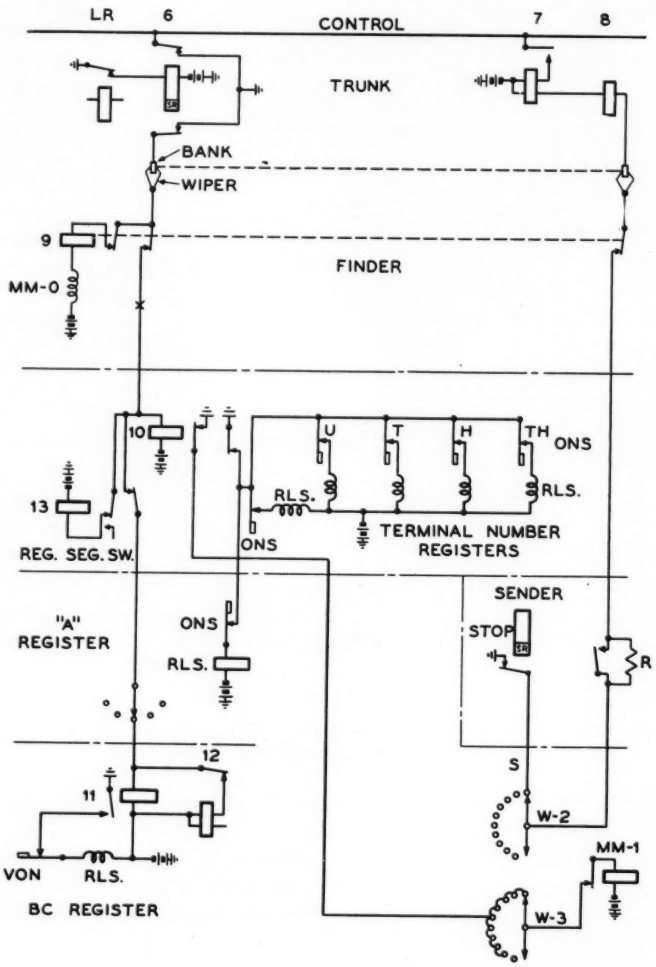

Figure 13. Release Circuits.

digits, a Strowger switch (two motions, up and around) will serve, with as many wipers as the largest number of digits in the directive. For the usual three-digit office code, a minor switch for the *A* digit and a Strowger switch for the *B* and *C* digits will serve, the Strowger switch having the same number of wipers as the greatest number of digits in the directive.

Having seen how the call number is registered and how several functions are performed, let us see how they are controlled and coordinated in sending out the directive. Assume a call number *324-5342*. According to Figure 4, the first digit has rotated the *A* register three steps, and the next two digits have lifted the wipers of the *BC* register two steps and rotated them to the No. 4 set of bank contacts. Further, the dialing of the terminal number has set the wipers at contacts *5-3-4-2* respectively, as shown in Figure 12.

Assume that to reach the distant office the Director must send the digits *4* and *1*. (The bank contacts of the *BC* switch were cross-connected

to the decimal terminals *4* and *1* on the IDF at the time of installation.)

Thus we have in the register bank multiple a complete representation of the digits which are to be sent, and the bank of the sender switch carries this bank multiple with the wires in numerical order. The sender is ready to obey the indications thus presented.

There is one exception: "Skip Digits". Because the decimal equivalent (*324*) of the office code requires only a two-digit directive, the upper pair of wipers on the *BC* switch is not needed. The pair is cross-connected on the IDF to two contacts on the bank of the *R* wiper of the sender sequence switch. As described later, this causes the sequence switch to pass by these wipers quickly without waiting for any impulse sending.

Sending the Impulses

As was illustrated in Figure 10, we are to govern the number of impulses sent in each digit by means of a grounded contact on the bank of a register. Figure 12 shows all eight wipers—four in the *BC* register and four in the registers for the line number. The ground is to be placed on these wipers in succession by means of wiper *S* of the sender sequence switch. Each time that the sequence switch advances, and thus grounds a new wiper, it starts the sender on a round of exploration by means of the "start sender" wire. When the sender switch has made a cycle and returned to the home contact, it advances the sequence switch by means of the "sequence wire."

To avoid complexity I have omitted from Figure 12 all the details which could be spared, leaving only those which make clear how translation of the office code and sending of the impulse digits are accomplished.

The *BC* register is controlled by the calling subscriber through a line relay *LR* in the trunk repeater. Assume that the wipers of the *BC* switch have been lifted by the second digit. As the line relay repeats the impulses sent by the subscriber, the rotary magnet *RM* steps the wipers around. At the same time the series relay *Se* pulls up and remains operated. It causes relay *F* to operate, which locks to a ground in the trunk repeater. When the third digit transmission ends, *Se* releases, and grounds the start wire for the sequence switch. Wiper *R* connects to the self-vibrating contact of the motor magnet *MM-1*, which promptly advances the sequence switch wipers one step. This puts the *S* ground on Wiper No. 1 of the *BC* switch, and at wiper *SW* the same start wire ground is applied to the impulse relay *IR* of the sender. As was described in connection with Figure 10, the interrupter *I*, acting through *IR* (Figure 12), steps the sender switch around to contact No. 4, having thus sent four impulses over the loop to the first selector.

At the beginning of impulsing, relay *D* pulled up to clear the loop for *IR*, and also pulled up *MM-1* of the sequence switch, holding it operated as long as the sender is operating.

Having sent the four impulses, the sender switch rotates around to its home position, both bank contacts of which are open. Relay *D* releases, thus releasing the motor magnet *MM-1* of the sequence switch, and advances its wipers to the next set of contacts. Here ground *S* is placed on wiper No. 2 of the *BC* switch to start the sender again, this time transmitting only one impulse.

Wiper *SW* has been the means for starting the sender. Its next two contacts are open, but the corresponding contacts of wiper *R* have "skip" wires leading to the bank contacts of the *BC* switch which are occupied by wipers No. 3 and 4. Hence the ground applied by wiper *S* operates to cause the motor magnet *MM-1* to rotate wiper *S* (and all the others) quickly past wipers No. 3 and 4 without sending any impulses to the loop.

Placing the start wire of the sequence switch under the control of the *BC* switch is to insure that the subscriber has dialed all of the office code. The directive cannot be specified until all the code digits are registered. But after that time the directive can be sent, without waiting for the registering of the line number.

But the terminal number, though sent out as received, cannot be sent until it *is* received. For this reason, the starting of the sender is now changed to off-normal springs *ONS* on the line registers. When any one of them is dialed away from its normal position, the *ONS* ground a wire leading to the bank of the wiper *SW*. Thus the

sender can transmit each digit in succession as fast as it is registered.

Holding Circuits and Release

During the registering of the call number and the sending of the directive, ten switches are held — either passively or actively. The holding circuits for these are shown in Figure 13. In the upper left corner of the diagram are the line relay *LR* and the associated slow relay *6*, both of which are located in the trunk between the incoming line and the first selector. The slow relay holds the trunk from releasing, even while *LR* is impulsing into the director.

The main holding circuit passes from the slow relay *6* to the finder switch, thence through the register sequence switch and the code *A* register, to end in the *BC* register switch. In the finder switch, relay *9* is holding the connection through its wipers, while in the *BC* switch relay *11* is with-holding ground from the release magnet. Relay *10* in the register sequence switch is controlling the release of six switches: the sequence switch, the *A* register, and the four line registers *(Th, H, T,* and *U)*. In addition, it is in a position to ground the *W-3* bank of the sender sequence in order to chase it home.

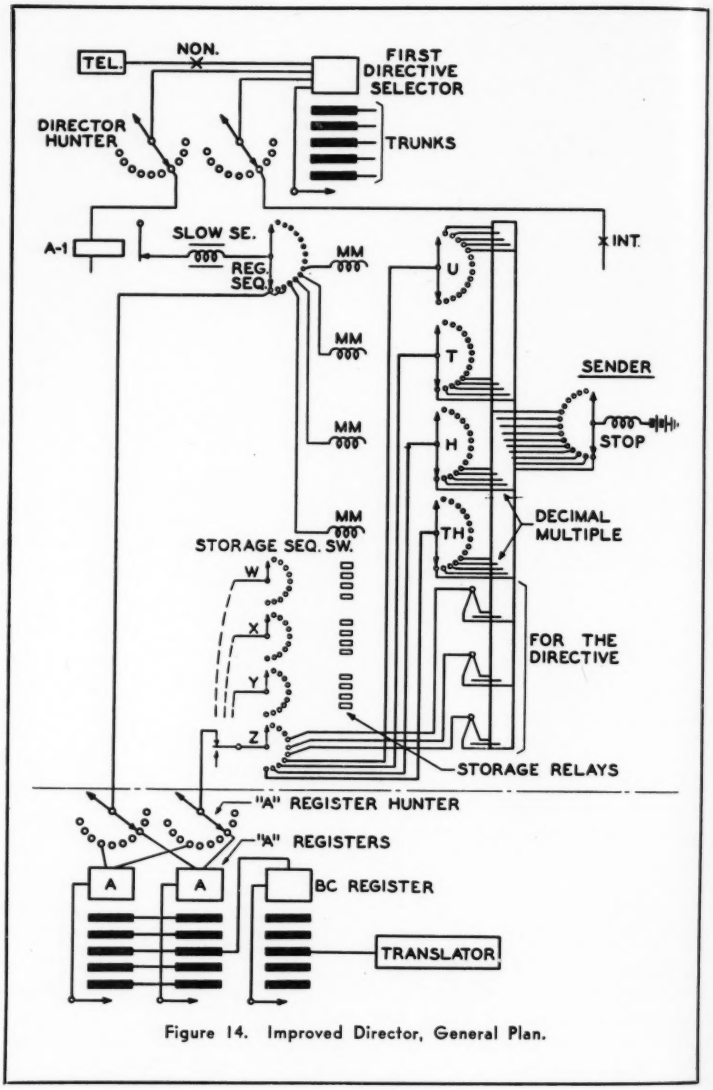

Figure 14. Improved Director, General Plan.

In Figure 13 we note also the means for switching the subscriber line through to the selectors and thus to the called telephone. Relay *7* is the through-switching relay in the trunk circuit. It is connected through the finder switch to the sender and the sender sequence switch, as shown.

As soon as the sender reaches home from transmitting the last digit of the call number, relay *D* of the sender (Figure 12) falls back quickly, but the "stop" relay hangs on for a moment. The release of *D* permits the sender sequence motor magnet *MM-1* to release, which quickly snaps the wipers to their contacts *S*. This (see Figure 13) completes the path between the ground at the "stop" relay through bank and wiper *W-2*—again through the sender circuit, the finder switch, and to the switching relay *7* in the trunk circuit. Then the "stop" relay of the sender falls back.

The switching through of the telephone to the train of switches has cut off line relay *LR* of the trunk, so that it and the slow relay *6* release. This takes the control trunk ground from the entire system of five relays, affecting seven release magnets. Relay *9* severs the finder switch connection; relay *11* operates the release magnet for the *BC* switch; relay *10* of the register sequence switch operates the release magnet of the *A* register and all four of the release magnets of the line registers. In each such case the release magnet is cut off by an off-normal spring, which breaks its circuit when the switch reaches normal. Another ground contact on relay *10* grounds the bank of wiper *W-3* of the sender sequence switch, whereupon the motor magnet *MM-1* interrupts its own circuits and steps all its wipers around to the home position. The Director is now ready to care for another call.

In spite of the rather lengthy explanation above, the entire release time is very short, usually from one-half to one second.

The Later Director

Improvements have been made in the Director from time to time. From them have come interesting circuit structures resulting in economy of apparatus and increased flexibility. For example, in the arrangement I shall now describe, part of the apparatus is common to a number of Directors, being released as soon as its work has been done.

In Figure 14 the telephone *Telo* is connected through non-numerical switches *Non* to an idle first selector. Out of the associated relays come several wires to a Director hunter, by means of which an idle Director is found and seized.

At the right are the registers in which are to be stored the information which will guide the sender in transmitting groups of impulses to the train of numerical switches leading to the distant office and subscriber's line.

The dialed impulses pass through a relay *A1*, which repeats them to the register magnets. A series slow relay pulls up on the first impulse, to remain energized until the digit is registered. It then releases, and causes the register sequence switch *Reg Seq* to advance one step. Three office code digits are followed by the line number, which the register sequence switch delivers to the motor magnets of the four line registers in succession. The wiper and bank marked *Reg Seq* have wiper *U* on the same shaft. During the latter part of its rotation, this switch acts as the units register of the line number.

The storage relays with their sequence switch will handle the directive and later feed it into the decimal multiple.

Below the dashed line are four sets of apparatus which are common to as large a number of Directors as the traffic needs. First is the *A* register hunter, which finds and seizes an idle *A* register. This is a Strowger switch, whose vertical motion registers the *A* digit of the office code. Its wipers then rotate to find an idle *BC* register. The latter responds to the *B* and *C* digits of the office code, and connects the circuits to the translator *Trans,* which is associated with it for that particular set of bank contacts.

The dialing of the terminal number is now switched to the magnets of the registers *Th, H, T* and *U*.

After receiving the ABC digits, the translator at once sends back through other wipers of the *BC* and *A* registers the complete designation of the directive which will guide the call to the desired office and line. This directive is delivered to the storage sequence switch's four wipers, which guide each digit to its group (four relays each). Here each digit is held by the locking up of the relays which were energized. The output contacts of each group of four relays are represented by a "delta"-shaped symbol to the right of each (explained in Figure 15). The contacts lead into the common decimal multiple cable.

The result is that we have connected to the decimal multiple a number of settings equal to the four terminal digits, and to the number of digits in the directive. Now the apparatus below the dashed line may be disconnected, because it is no longer needed for the call which we are considering.

The sequence switch associated with the storage relays now takes control, connecting a ground on the first directive setting, and starting the sender. The latter sends impulses into the loop leading to the first directive selector, which stops when the

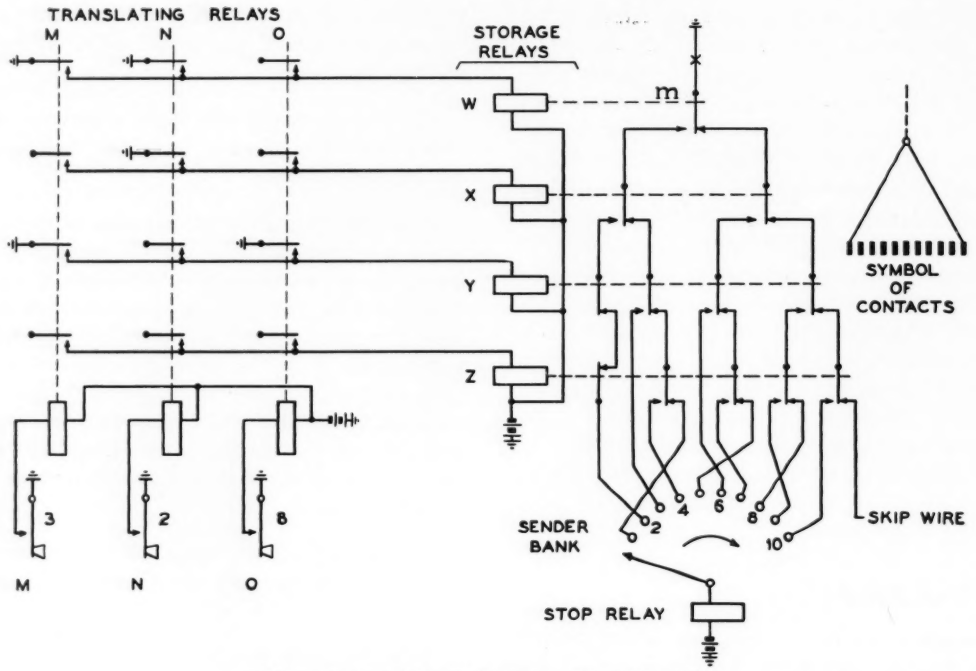

Figure 15. Translation and Storage, General Principles.

wiper arrives at the grounded contact. The stop relay ends the impulses, and causes its sender sequence switch to influence the storage relays so that they ground the next directive setting. This causes the next directive to be sent, with the number of impulses indicated by the existing ground on the decimal multiple. In the same way all the rest of the directive digits are transmitted.

In like manner each terminal register controls the impulses in its digit, until the entire number has been transmitted. At this moment, the wipers of the connector in the distant office are resting on the contacts of the called line. The events which follow are common knowledge.

Translation and Storage

The basic circuit device is illustrated in Figure 15. Consider the four relays at the right and their contacts, mostly arranged in series with each other. If all four are energized, there is no path from the grounded spring to the sender bank. If all four relays are normal, there exists a path from the grounded spring to the "skip wire," which leads to that bank of the storage sequence switch to whose wiper the motor magnet is attached by its self-vibrating contact. It enables fewer directive digits to be used than the maximum provided.

Now consider the three relays at the left, and their contacts. Each relay has four main springs, one for each of the relays on the right. But the main springs are grounded according to a plan. If we should press the key *M*, relay *M* would ground and operate relays *W* and *Y* at the right. Now trace the path from the main spring of relay *W* downward to the sender bank: it will be observed that the No. 3 contact is grounded. Hence, if the sender moves its wipers as usual, the stop relay will pull up when the wiper reaches No. 3. (Notice that the transfer of information is practically instantaneous—the storage relays pull down together.)

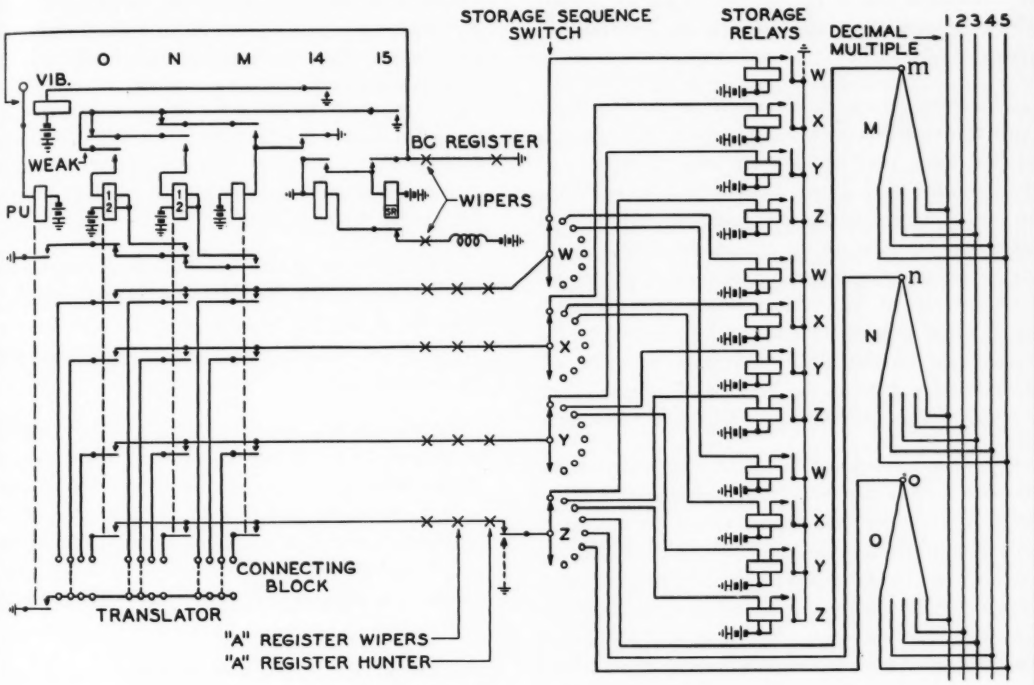

Figure 16. From Translator Through Storage Into Decimal Multiple.

If we had pressed the *N* key, it would have grounded contact No. 2 on the sender bank. Likewise, the *O* key would have grounded the No. 8 contact. Thus, by pressing any key we can cause the sender to transmit a certain number of impulses before being stopped. Reference to Figure 7 will recall the action.

The complete code is as follows:

Relays operated:
W WX WY WZ X XY XZ Y YZ Z
Digit Produced:
1 2 3 4 5 6 7 8 9 0 (or 10)

It will be observed that the four wires between the *MNO* relays and the *WXYZ* relays are few enough to permit considerable switching without too many wipers. This is needed because these four wires must be carried back (see Figure 14) through the banks and wipers of the *BC* register, the *A* register, and the register hunter, to the storage relays which feed into the decimal multiple into which the sender bank is wired. (The symbol to the right in Figure 15 represents the group of contacts.)

The essentials of how a translation is transferred to the storage relays are shown in Figure 16. I assume that the directive has only three digits, *M, N* and *O,* represented by the relays at the left. In addition to their operating contacts, each relay has four main springs, corresponding to four wires *W, X, Y* and *Z*—the basis of the transfer code.

To the right are the storage relays, three groups of four relays each. Each group has four relays, *W, X, Y* and *Z*. The right hand winding of each with its contact enables each one to lock itself in an energized position. The left hand windings are the pull-up windings, by means of which the codes coming from the translator will operate such stor-

age relays in each group as the desired decimal digit requires. It is the storage sequence switch which delivers the code for each digit to its own group of relays.

The three relays *M, N* and *O* in the translator must be caused to operate and release in sequence, so that each may ground the desired wires. At the bottom I have shown a small connecting block, by means of which the four main springs of each relay may be wired to the ground bus bar to make the code. Suppose, for instance, that the necessary directive is *325*. Thus, when relay *M* pulls up, it must ground wires *W* and *Y*, shown by the dotted line on the block. Likewise, relay *N* will momentarily ground the *W* and *X* wires. Then relay *O* will momentarily ground the *X* wire alone.

The storage sequence relay steps its wipers along by means of a control circuit not shown. When relay *M* is pulled up, the wipers of the sequence switch will be resting on their first contacts, leading to the four storage relays in the *M* group. Hence, only relays *W* and *Y* will be pulled up and locked. The contacts represented by the delta-shaped symbol (Figure 15) will connect spring *M* to wire *3* in the decimal multiple.

When relay *N* in the translator (Figure 16) takes its turn, the wipers of the sequence switch will be resting on their second contacts, leading to the relays in the *N* group. Thus, relays *W* and *X* will operate and lock. When relay *O* in the translator takes its turn, the sequence switch will guide the ground connection to relay *X* in the *O* storage group.

The sequence operation of the *M, N, O* relays in the translator is accomplished as follows. When the *BC* register stops its wipers on the set of contacts, relay *14* pulls up in series with a relay in the *BC* switch. Relay *14* pulls the armature of the vibrator *Vib* and holds it there, operates relay *M*, and pulls up relay *15*. The latter locks itself, grounds the holding circuit for relay *M*, and cuts off relay *14*. On falling back, relay *14* releases the vibrator armature which, being weighted, swings back and forth like a pendulum. Its first swing to the left pulls up relay *PU*, which grounds the translator block bus bar and energizes the weak winding of relay *N*. Relays *M, N* and *O* are of the two-step type, and hence, relay *N* closes its "weak" contact. When the vibrator causes *PU* to release, the short circuit is removed from the "in" winding of relay *N*, which promptly operates and locks itself to the ground on relay *15*. Relay *M* falls back, and the code wires are grounded by relay *N*.

The same operations take place during the next closure of the vibrator, operating relay *O* and releasing relay *N*. This permits relay *O* to have its chance at the code wires.

The last digit of the directive thus being stored, the circuits are cut off at the sequence switch, so that the *A* and *BC* registers and the translator are released and return to normal, ready to be seized by another call.

In the storage sequence switch, the *Z* wiper is switched to a circuit where it receives ground. From here on it operates like a sender sequence switch, working with the sender (Figure 14) in applying ground to each of the directive springs *M, N* and *O*, in turn, and afterward to the wipers of the line register, *Th, H, T* and *U* in succession.

Incidental Functions and Services

Not all calls go through with the regularity which I have assumed. Some of the following incidentals must be expected:

(1) The subscriber removes the handset but does not dial.

(2) He dials only part of the call number and then stops.

(3) He dials a non-existing office.

(4) He dials a dead line number.

There is not room in this article to describe the above considerations in detail, but adequate means for dealing with them have been provided. The first two are handled by a slow time device, which comes into play if any Director is held longer than a predetermined limit, after which the connection is released. The third occurrence is handled by an information desk. The fourth is handled on the banks of the connectors as is done in most automatic exchanges.

Trunking to manual offices with call indicators, which display the number in front of the operators,

is handled by inserting a coder in the trunk beyond the first selector (or a later selector). This changes the decimal digits into the kind of code used, and sends it to the manual switchboard. Thus it does not affect the structure of the Director. Incoming calls from manual to automatic are put through by some kind of calling device provided for the operator—either the push-button type or the dial type (for small manual boards). Such calls go directly into the automatic switches, and the Director is not involved.

Enough has been discussed and illustrated to show rather conclusively that some kind of translating device can be made which will, from any office code, pick out any prescribed decimal number, and that this number will reliably control an impulse sending device. Communication engineering is especially rich in devices and combinations, and consequently we need not care very much exactly how the inter-office selectors are arranged, or how the multi-office exchange is laid out. We can make the complete Director assembly do whatever is necessary to direct a call to the desired distant office and connect with the desired telephone.

THE CONVOTROL: A NEW BATTERY CHARGER

By O. D. GRANDSTAFF

SYNOPSIS: ***Constant voltage charging method for longer battery life—variables affecting charger voltage — three sizes of Convotrol—details of mechanical and electrical construction—magnetic characteristics of regulator—performance curves related to voltages.***

THE Automatic Electric Convotrol is a new type of battery charger for use in the constant voltage floating method of battery charging. It employs selenium dry disc stacks for the rectifying elements and a static regulator for automatically varying the charging rate. This regulator has a precision pilot unit calibrated to a single dial control for selecting the desired floating voltage.

In the constant voltage method of charging the voltage is held at 2.15 volts per cell, and the charging rate varies according to the condition of the battery. When the battery is discharged its voltage is a little below 2.00 volts per cell, and remains at about that figure until it is nearly up to full charge. This 0.15 volt difference causes the charger to operate at its full rating until the battery voltage begins to rise. Continued charging at a high rate with the battery nearly charged, however, would cause the voltage to increase to 2.4 or 2.6 volts in a short time and the cells would gas excessively, resulting in considerable loss of water. But when the charging voltage is held constant at 2.15 volts per cell, the charging current tapers down just enough to prevent excessive gasing and finishes the charging at the maximum safe rate.

A constant voltage charger continuously floating the battery also furnishes power directly to the load. Soon after a load is connected, the battery voltage tends to drop to 2.00 volts per cell, but since the charger voltage of 2.15 volts per cell is higher, current flows from the charger instead of from the battery. This inactivity of the battery increases its life and keeps it charged at full capacity for use during peak loads and times of power failure.

A charger must have a high degree of stability to provide constant voltage charging. Since the charger voltage of 2.15 is only 7.5 percent greater than the battery voltage of 2.00 volts, the output voltage must be held very accurately for the battery to be charged up to full capacity in the shortest practical time and yet not be overcharged. There are many variables that affect the voltage of a charger, such as line voltage fluctuations of plus or minus 10 percent, frequency variations in some localities, internal voltage drop from no load to full load, aging of the rectifiers, and changes of voltage drop due to heating. A good means of compensating for all these variables is necessary for constant voltage charging.

The Convotrol provides such compensation in a straightforward manner. Since it is the output voltage that must be kept constant, its charging rate is controlled wholly by the voltage at the output terminals. A new regulator unit is used which responds to any tendency for the output to deviate from the selected floating voltage. The regulator unit is highly stable since it consists only of reactors and rectifiers, all controlled by a pilot unit which has a permanent magnet as the standard of reference. The entire unit is impregnated with a baked insulating varnish for permanence.

Construction of the Convotrol

Figure 1 shows three sizes of Convotrols, rated respectively at 3, 6, and 12 amperes, 50 volts. All are similar in appearance and have the same controls: an on-off switch, a voltage dial calibrated from 44 to 56 volts, and an ammeter. The fuses are behind a small door below the control panel. All sizes use the same regulator and are constructed in much the same way. A conservatively rated 3-ampere 50-volt selenium rectifier stack is used, with one stack in the 3-ampere, two in the 6-ampere, and four in the 12-ampere size.

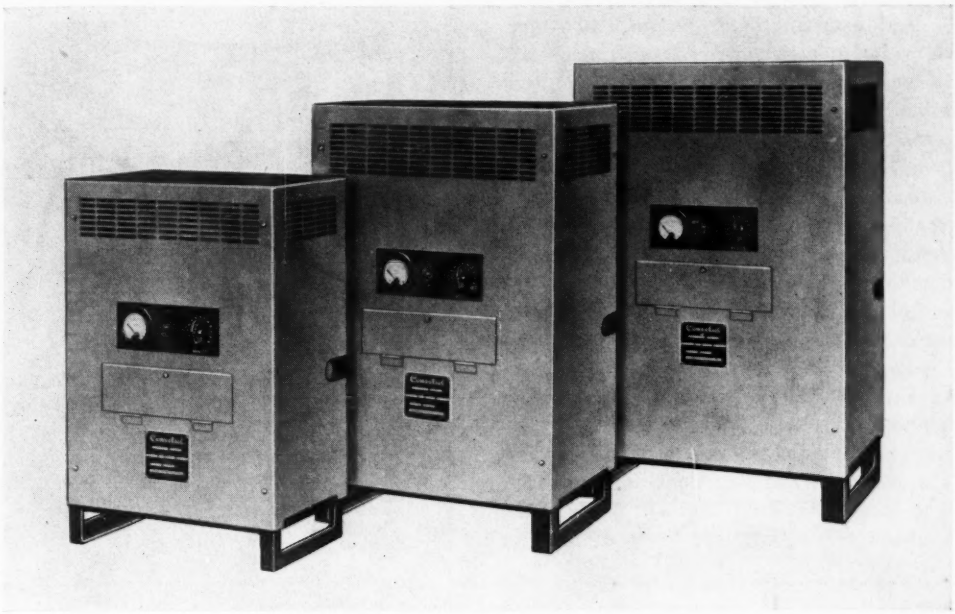

Figure 1. 3, 6 and 12 ampere, 50 volt Convotrols.

The Convotrol cabinet is designed for natural draft cooling by means of its chimney type ventilation system. Sturdy legs hold the bottom of the Convotrol up to permit plenty of cool air to flow up through the selenium rectifier stacks and around the warm transformer and reactors. A solid top prevents dust from falling into the cabinet. The upper ventilating openings are on the front and sides. The cover slides off the front so it can be removed easily when other equipment is mounted closely around the Convotrol.

Figure 2 shows the location of parts inside the cabinet. At the top is the regulator unit. In the front center is shown the control panel, with the fuses just below. At the bottom are the main selenium rectifier stacks. Figure 3 shows the wiring diagram. The transformer has two primary windings connected in series with the two alternating current coils of the saturable reactor. These windings may be connected in series for a 250-volt line or in parallel for a 115-volt line. The secondary of the transformer is connected to the full wave rectifier stack and its low voltage taps supply a small amount of power to the regulator unit. A choke coil in the negative output lead filters the ripple voltage down to less than 50 millivolts to eliminate hum on the talking circuits.

The saturable reactor has two identical outside coils wound with large wire for carrying the primary current of the transformer. These coils are poled so as to cause their flux to go around the outer sides of the core and not link the center coil. The direct current output of the regulator unit energizes the center coil, causing flux from the center leg to traverse the cores of both outside coils. The impedance of the outside coils varies with the amount of core saturation and accordingly changes the voltage drop to the transformer primary. This alters the secondary voltage on the rectifier stack from about 55 volts at no load to 95 volts at full load.

Regulator Unit

The regulator unit is in a rectangular metal cover with its control rectifiers—two small cop-

per oxide bridges and three selenium bridges—mounted on one side. A terminal strip provides for nine leads including input, output, and power leads. The input, designed for approximately 42 volts, is connected through the calibrated control rheostat and the calibrating resistors *(R1, R2 and R3)* to the output of the Convotrol. Resistors *R2* and *R3* affect the voltage spread covered by the control rheostat, while *R1* controls the drop between the rheostat and the regulator unit. Resistors *R1* and *R3* are mounted and wired so that moving the sliders to the right increases the output voltage. The control dial is calibrated by making adjustments at two voltages, preferably near the ends of the scale. Resistor *R1* has the greatest effect at low voltages and *R3* the greatest at high voltages, although both affect all voltages to some extent. A prior approximate adjustment is made accurate by slight changes in *R1* and *R3*. Convotrols are calibrated at the factory and normally require no further adjustment.

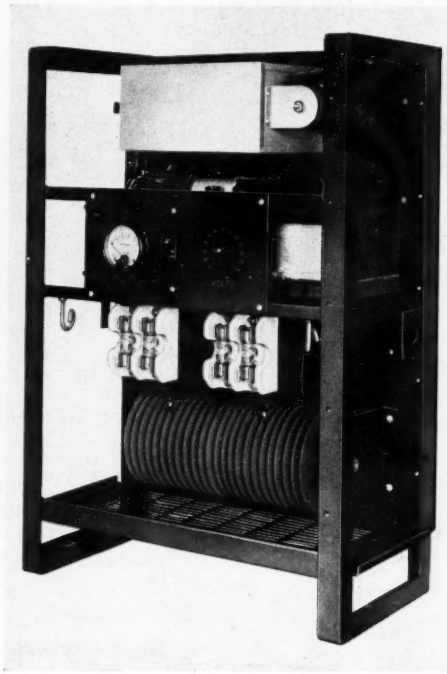

Figure 2. 3 ampere Convotrol, cover removed.

The Pilot

In the pilot, which is located in the regulator unit, rests the full control of the Convotrol. It continually measures the output voltage and regu-

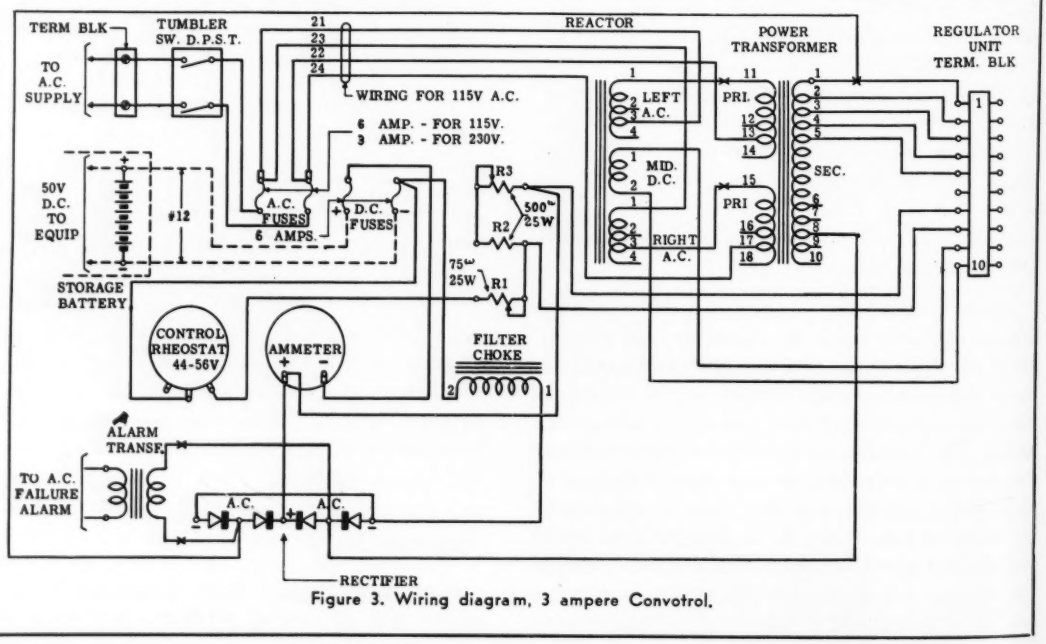

Figure 3. Wiring diagram, 3 ampere Convotrol.

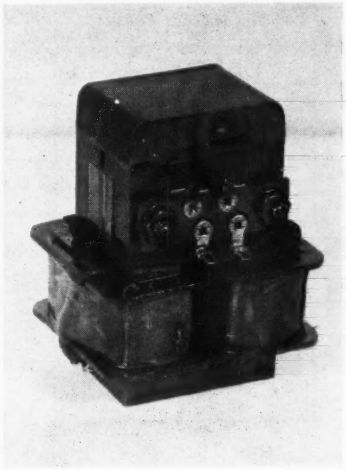

Figure 4. Convotrol pilot.

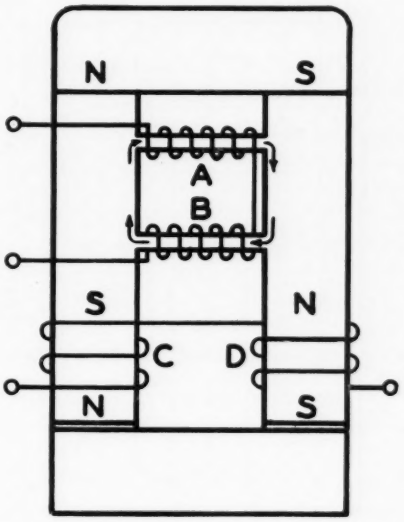

Figure 5. Diagram showing pilot structure.

lates saturable reactors within the regulator unit to increase or decrease the charging rate as the voltage drops or rises.

The pilot, shown in Figure 4, has an Alnico permanent magnet at the top and two electromagnetic coils at the bottom which are connected to the 42-volt input terminals. A large magnetic core couples the electromagnet with the permanent magnet. Another core, laminated and very small in cross section, is coupled magnetically across the large core between the permanent magnet and the electromagnet. It has two coils which are connected in series aiding to cause their magnetic flux to stay within the laminated core. These various pilot cores and windings are shown diagrammatically in Figure 5.

The electromagnet and permanent magnet are poled to aid each other, so that the flux of the permanent magnet passes through the core of the electromagnet. When the ratio of magnetomotive force of the permanent magnet to the magnetomotive force of the electromagnet is equal to the ratio of reluctances above and below the laminated core, all of the flux of the permanent magnet passes through the electromagnet. When the voltage decreases, however, the electromagnet becomes weaker and a portion of the permanent magnet flux takes the shorter path through the laminated core. The large core carries so many lines of flux that a small unbalance diverts enough flux through the laminated core to saturate it. Hence a small change of battery voltage will cause saturation of the laminated core and the impedance of its coils will change from maximum to minimum.

The curve in Figure 6 shows the characteristics of the pilot. With the battery voltage at zero, flux of the permanent magnet completely saturates the laminated core and maximum current flows through the alternating current coils. The core remains completely saturated until the battery voltage rises to 30. Between 45 and 55 volts the impedance changes very rapidly; a portion of this range near 50 volts is used to control the charging rate of the Convotrol. As the battery voltage is increased above 55 volts, there is a range between 55 and 63 volts where the impedance remains high. Any further increase causes the impedance to decrease rapidly to the same impedance as at zero volts, as shown by the broken line portion of the curve. In the portion of the curve above 63 volts, since the electromagnet is stronger than the permanent magnet the flux of the electromagnet

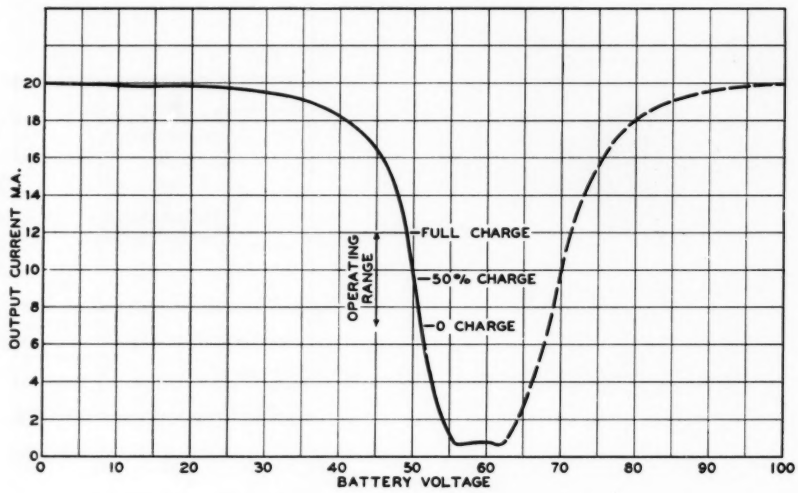

Figure 6. Curve showing pilot characteristics.

saturates the laminated core in the same manner as the permanent magnet flux does below 55 volts. The broken line portion is not used for the Convotrol, as it would give improper control—the charging rate would be increased with rising battery voltage.

Convotrols can be designed to function on any battery voltage. In the regulator unit, only the d-c coils of the pilot need be changed. The transformer secondary, main rectifier stack and filter choke must be designed for the desired output voltage.

The curve in Figure 6 shows that the output of the pilot changes rapidly with a small change of battery voltage. In actual operation in the Convotrol, however, the sensitivity is much greater due to the power for the pilot being supplied by the transformer that feeds the main rectifier stack. As mentioned previously, the stack voltage varies from 55 to 95 volts on a 23-cell battery to handle the charge from no load to full load. The a-c power to the pilot also changes proportionately from 2.2 volts at zero charge to 3.7 volts at full charge. Since the curve of Figure 6 was taken with a constant voltage of 2.5 on the a-c coils of the pilot, it will be understood that considerably greater change of the pilot output results when its power voltage increases along with the decrease of the battery voltage.

The variable voltage of the power supplied to the regulator also assists in providing equally good control of either a 21-cell or a 26-cell battery merely by changing the single dial control. For example, the secondary or stack voltage varies from 45 to 90 for 21 cells and from 65 to 105 for 26 cells. The power voltage to the regulator varies correspondingly from 1.8 to 3 and 2.7 to 4 volts. The different power voltages automatically applied to the regulator unit enable the pilot to cause the Convotrol to change from zero to rated charging current regardless of the number of cells floated, when the single dial control is set for the proper floating voltage.

Frequency Range of Convotrol

Convotrols will function over a considerable range of power frequency. There are no resonant circuits involved—only reactors are used. Small variations that do result from frequency change are readily compensated by the pilot, where the control is not affected by frequency but depends on the permanent magnet and direct current electromagnet coils operating from the battery. The

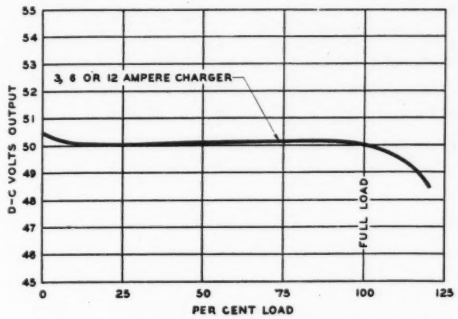

Figure 7. Curve showing voltage output in relation to load.

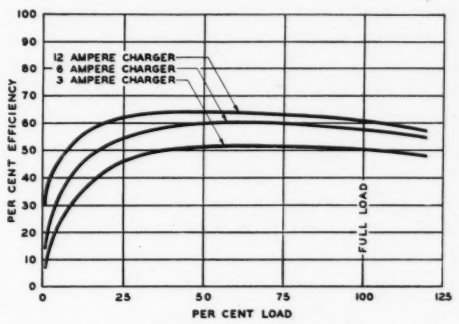

Figure 8. Curves showing efficiency in relation to load.

Convotrol can be connected to power of any frequency from 48 to 65 cycles without changing any controls, and with negligible alteration in output voltage.

Output Voltage Characteristics

The Convotrol maintains a substantially constant floating voltage from no load to full load and then drops rapidly to prevent overloading the rectifier stacks. The 50-volt Convotrols of all current ratings float the battery as shown by the curve in Figure 7. Actually, the voltage may vary as much as $\pm$ 1.0 from the dial setting from no load to full load, due to the lag in the magnetization and demagnetization of the saturable reactors. But as the battery load fluctuates, the magnetization eventually reaches a mean value and the battery is floated at about the same voltage regardless of the charging rate.

The Convotrol operates at very high efficiency for a self-controlled dry disc charger. Curves in Figure 8 show that the efficiency rises above fifty percent at light loads and remains at high efficiency beyond full load. Since a constant voltage charger is floated on the battery 24 hours a day, the no-load power during idle hours is also important. Due to the principle of operation of the regulator unit, its control currents are at a minimum at zero charge. Also the leakage of the selenium rectifiers and the transformer losses are low. This is borne out by the following table of input powers:

Convotrol Size	*No-Load Power*
50 volts, 3 amp.	25 watts
50 volts, 6 amp.	40 watts
50 volts, 12 amp.	60 watts

The Convotrol has the characteristics desired by both equipment engineers and operating companies. Since it is self contained, it eliminates many equipment and mounting problems. It is easy to install and maintain, has practically an unlimited life, ensures maximum battery life, and operates with very low power consumption.